DOER

Massachusetts Department of Energy Resources

MASSACHUSETTS CLEAN ENERGY CENTER

MASSACHUSETTS ENERGY STORAGE INITIATIVE

STATE OF CHARGE

September 27, 2016

Customized Energy Solutions
Analyze · Simplify · Implement

ALEVO ANALYTICS

DAYMARK ENERGY ADVISORS

Sustainable Energy Advantage, LLC

Energy Storage Initiative
Goals of the Study

"The Commonwealth's plans for energy storage will allow the state to move toward establishing a mature local market for these technologies that will, in turn, benefit ratepayers and the local economy,"

- Analyze the storage industry landscape, review economic development and market opportunities for energy storage, and examine potential policies and programs that could be implemented to better utilize energy storage in Massachusetts.
- Provide policy and regulatory recommendations along with cost-benefit analysis
- Engage stakeholders such as ISO-NE, utilities, the Massachusetts Department of Public Utilities (DPU), storage industry, U.S. Department of Energy (DOE) labs, and other interested parties

The Commonwealth can nurture and grow the energy storage industry through programs and initiatives aimed at both attracting business and deploying the technology.

Study Results

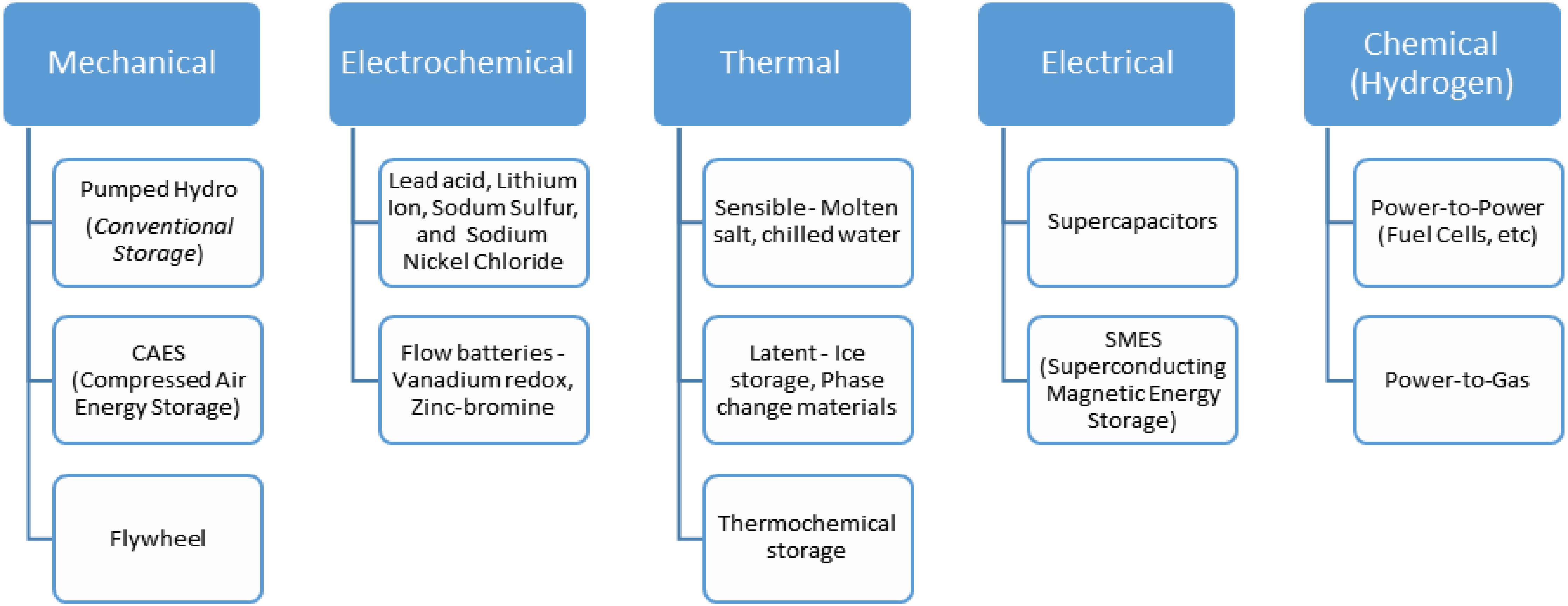
- Recommends a suite of policies designed to promote the development of **600 MW of advanced energy storage in Massachusetts by 2025.**

- Provides $800 million in system benefits to Massachusetts ratepayers.

- Policies will increase grid resiliency and reduce greenhouse gas emissions

- Recommendations include:
    - *Demonstration funding through the ESI, Inclusion in existing DOER and MassCEC grant programs, encouraging expanded use of energy storage in existing energy efficiency programs, considering energy storage as a utility grid modernization asset, amending the Alternative Portfolio Standard (APS) to include all types of advanced energy storage, Inclusion of solar plus storage in the next solar incentive program, and enabling pairing storage with renewables in future long-term clean energy procurements.*

Advanced Energy Storage Technologies



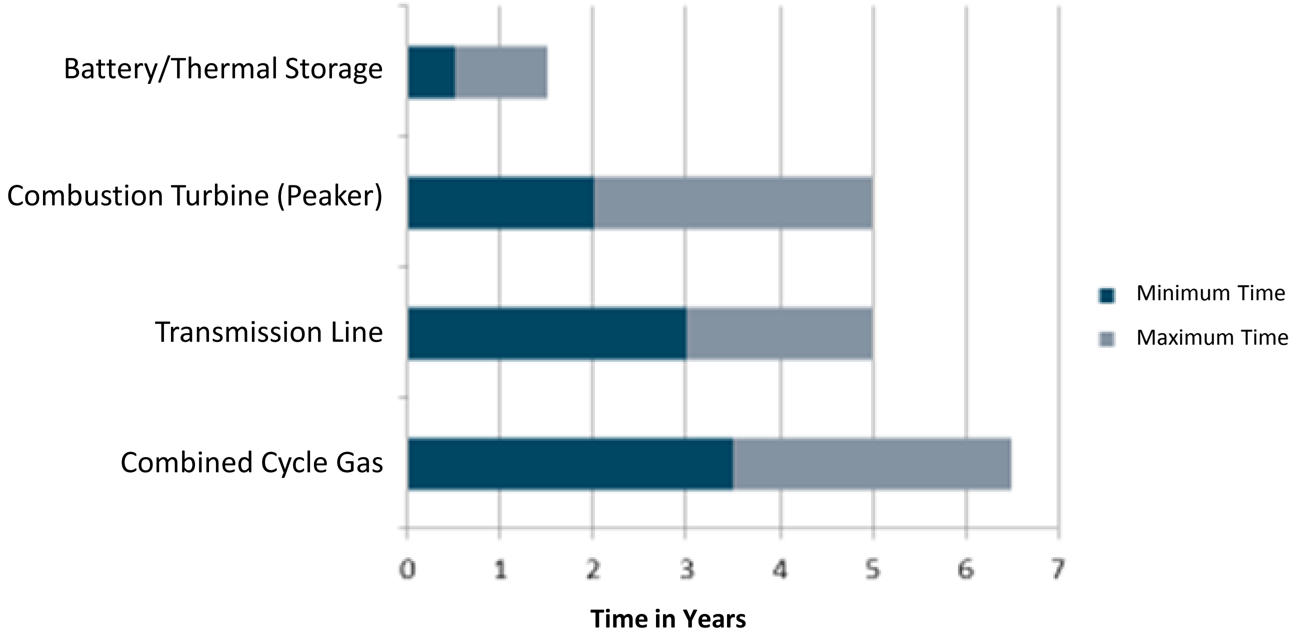
- Pumped Hydro Storage is often referred to as a "conventional" storage technology
- More recent emerging forms of energy storage such as batteries, flywheels, and new compressed air energy technologies are often referred to as "**advanced energy storage**".

Energy Storage Attributes

Energy storage resources can be installed much more quickly than traditional resources, reducing risk, and increasing technology flexibility

- Energy Storage is:
  - Proven technology
  - Modular and flexible in design
  - Useful in multiple applications
  - Quick to respond (dispatchable)
  - Easy to site
  - Quick to market

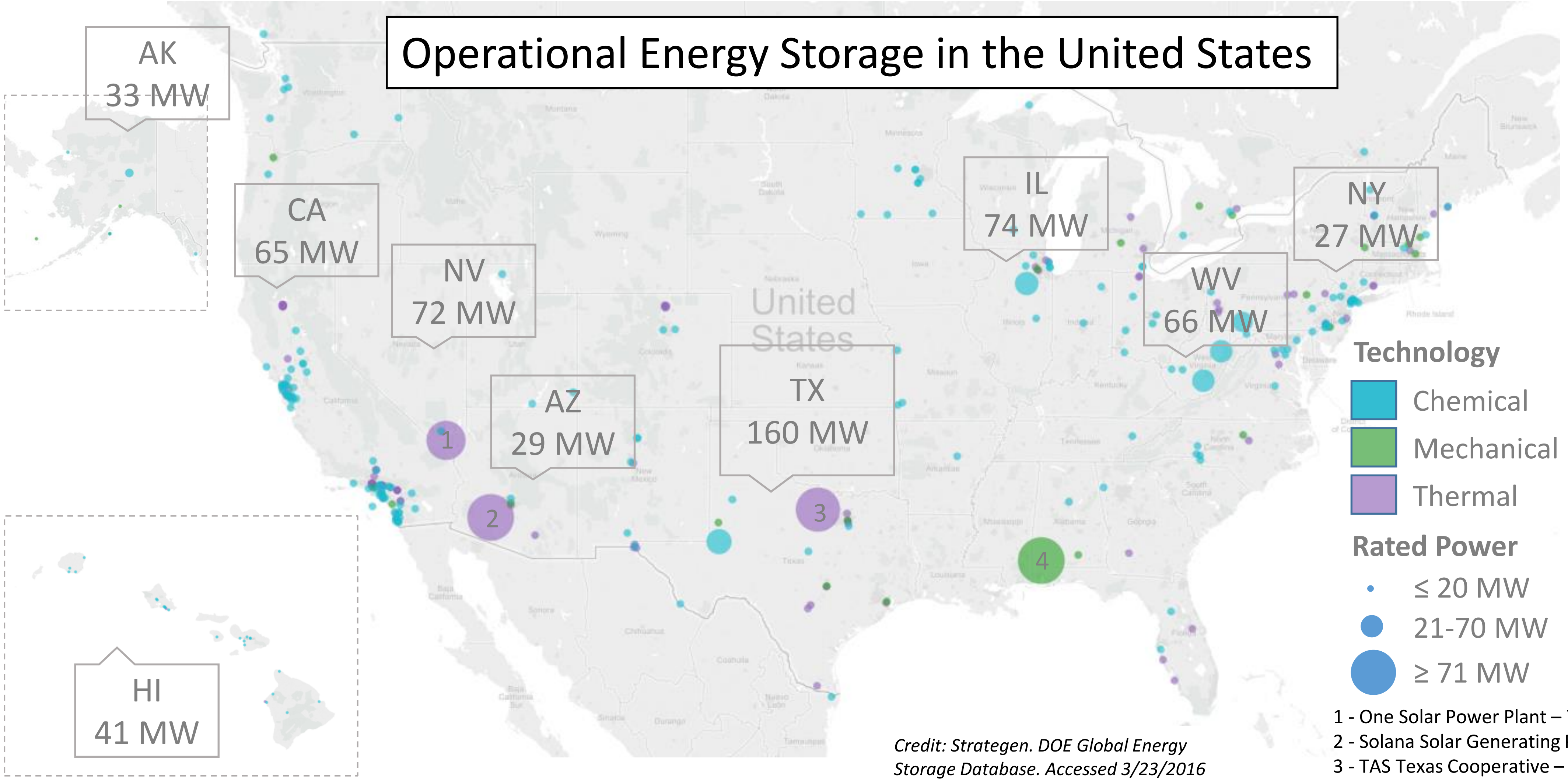
Siting, Permitting, and Installation Time by Resource



Energy storage solutions will deliver smarter, more dynamic energy services, address peak demand challenges and enable the expanded use of renewable generation like wind and solar. The net result will be a more resilient and flexible grid infrastructure that benefits American businesses and consumers."

\- M. Roberts, Executive Director, Energy Storage Association

Storage is Real: Growing Deployment in the US & Globally

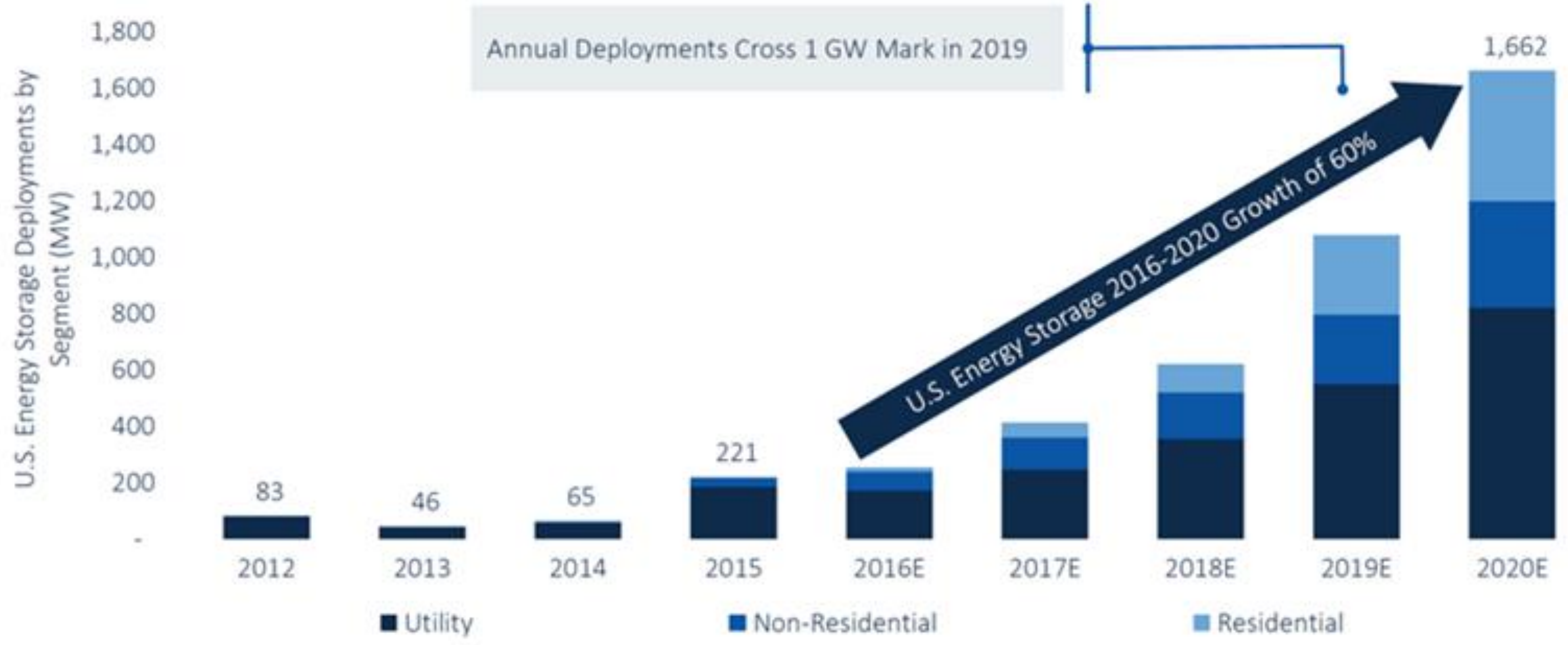


Credit: Strategen. DOE Global Energy Storage Database. Accessed 3/23/2016

1 - One Solar Power Plant – 72 MW
2 - Solana Solar Generating Plant – 280 MW
3 - TAS Texas Cooperative – 90 MW
4 - McIntosh CAES Plant – 110 MW

Advanced energy storage has moved out of the research and development phase. It is commercially viable and there are over **500 MW** operating throughout the US.

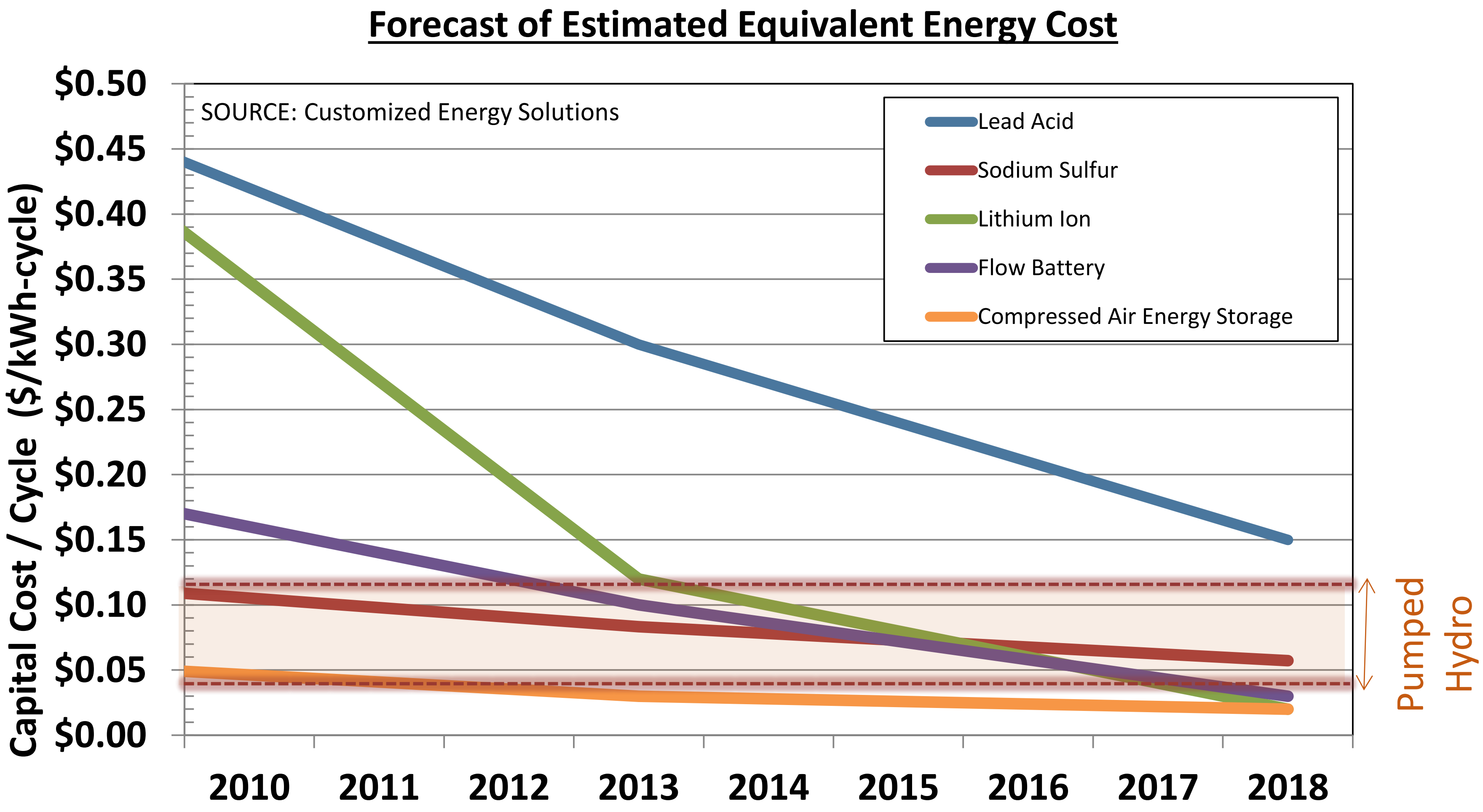
Advanced Energy Storage is Growing Rapidly



Annual US Energy Storage Deployment: > 1 GW by 2019, 1.7 GW by 2020

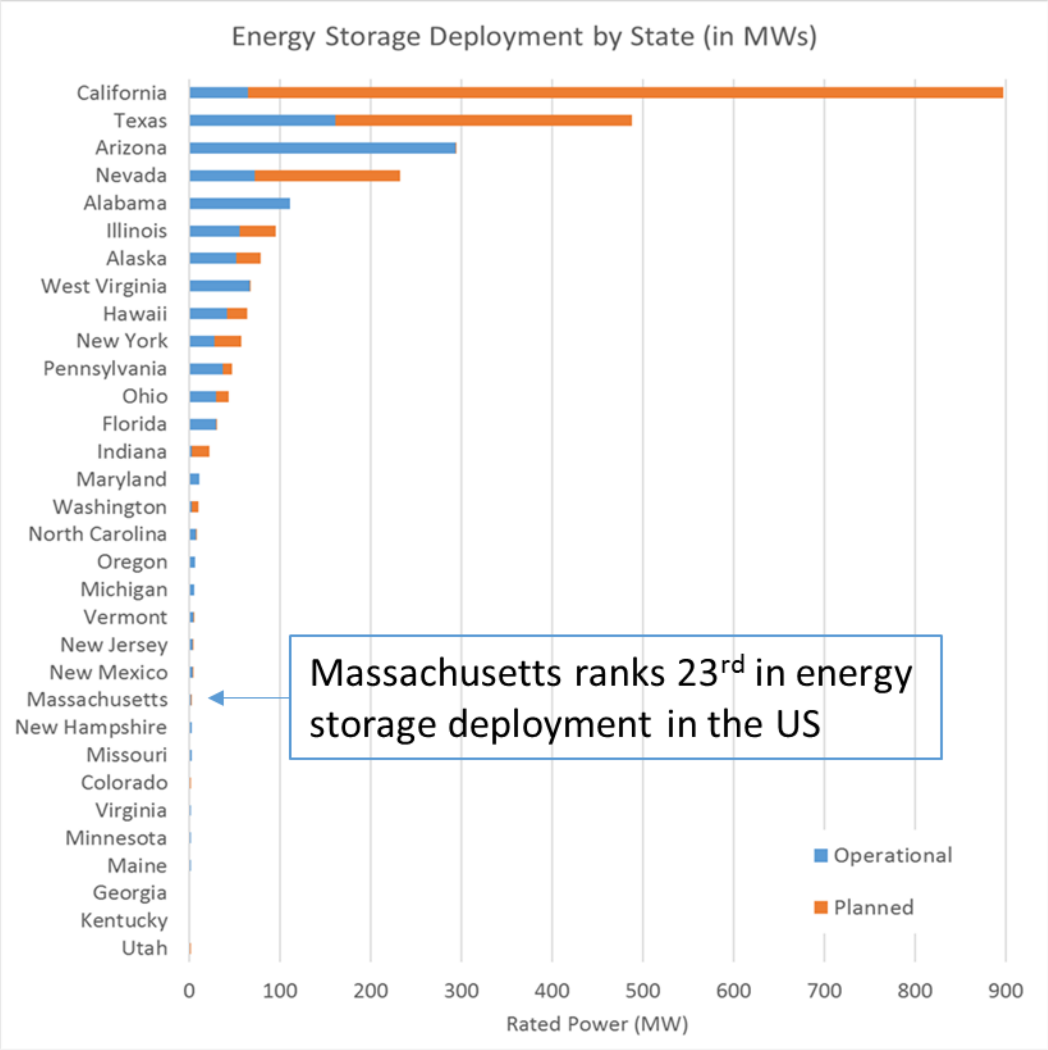
Cumulative US Energy Storage Deployment: 4.5 GW by 2020

Cost of Advanced Storage is Decreasing



In the ten years between 2008-2018, prices for storage technologies are significantly decreasing with Lithium Ion technology decreasing almost 90%

Growing Deployment in Other States



While many other states have already begun deploying large amounts of advanced storage capacity, Massachusetts is lagging behind.

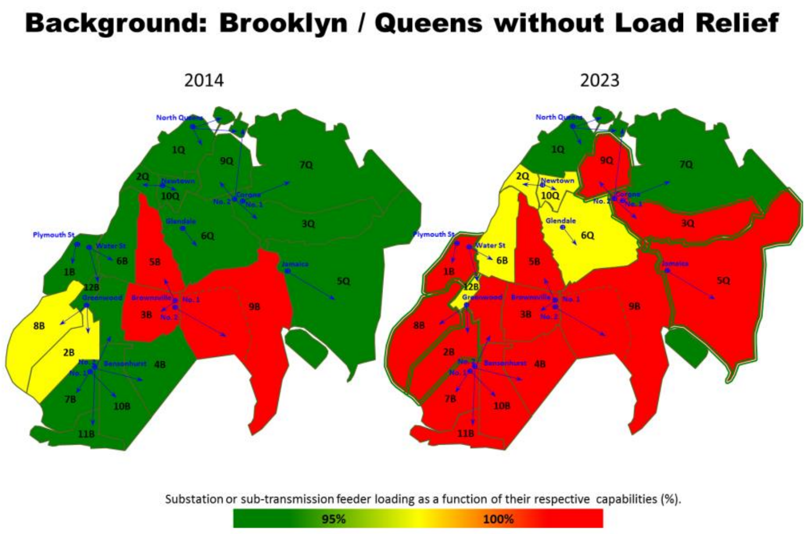
Other States are Using Storage to Address Challenges

California

- Storage will be utilized as part of the plan to replace 2,200 MW of Nuclear retirements, SCE announced procurement combination that included **261 MWs of energy storage** resources in conjunction with new baseload natural gas generation and new renewable generation

Texas

- Texas leads the nation with over 17,700 MW of installed wind capacity
- Duke Notrees project is analyzing how the integration of energy storage can compensate for the inherent intermittency of this renewable power generation resource

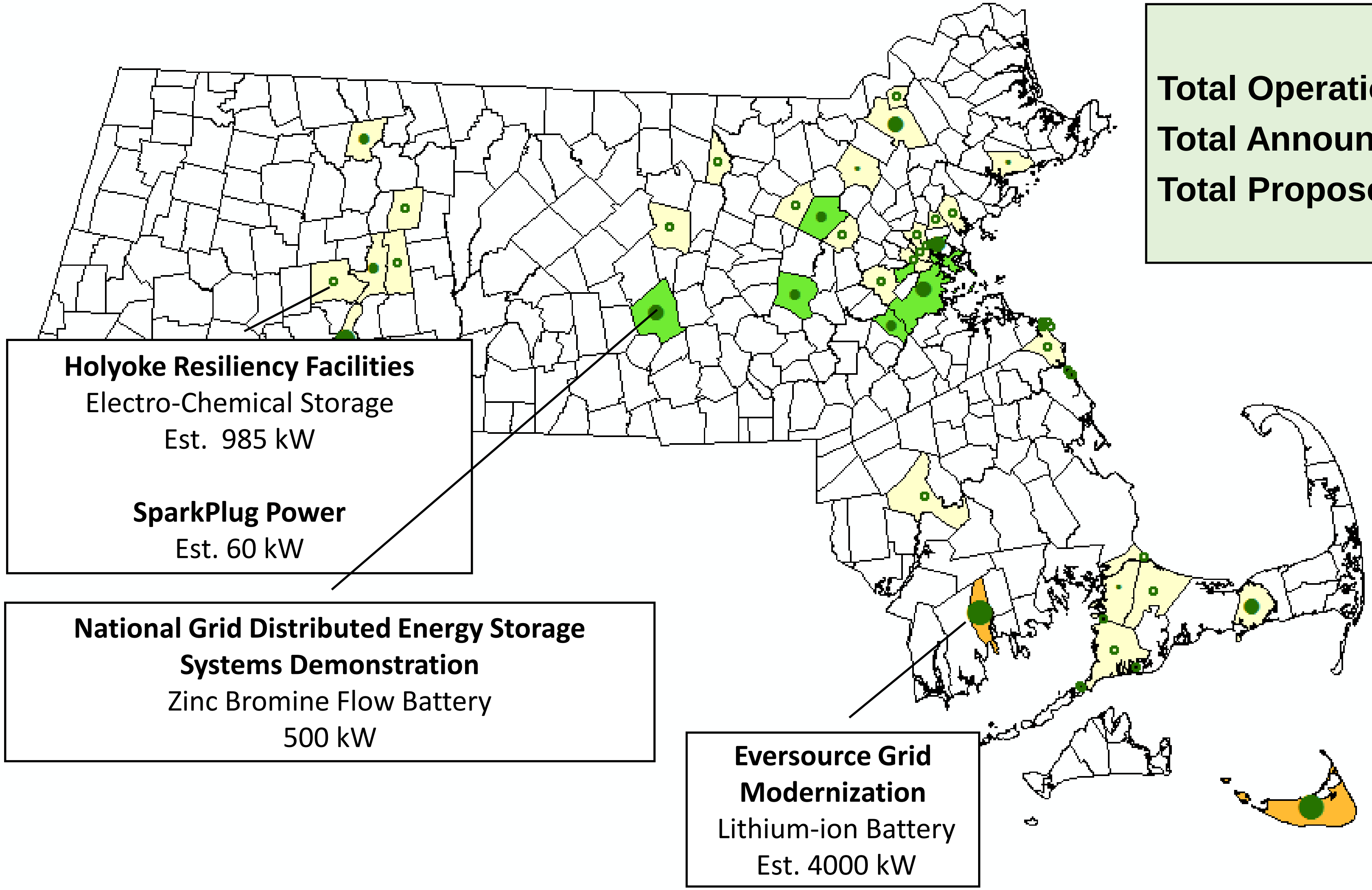


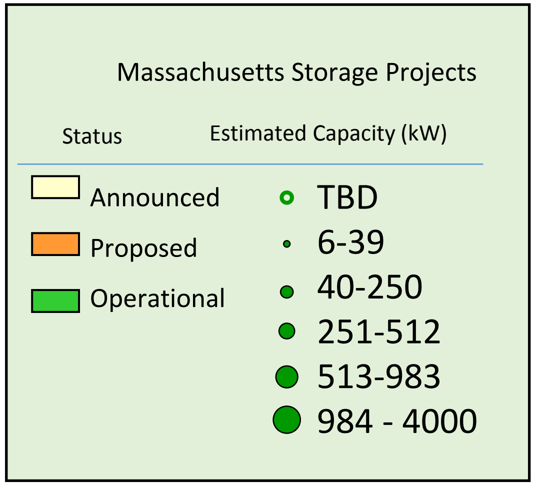
New York

- Con Edison in New York City is approved to use energy storage as part of the solution to **avoid a $1 Billion investment** in major substation upgrades
- They recently awarded a contract to install energy storage and demand management in Queens to furnish **100 MWs of load reduction**
- The storage will help meet load requirements in the densely populated area

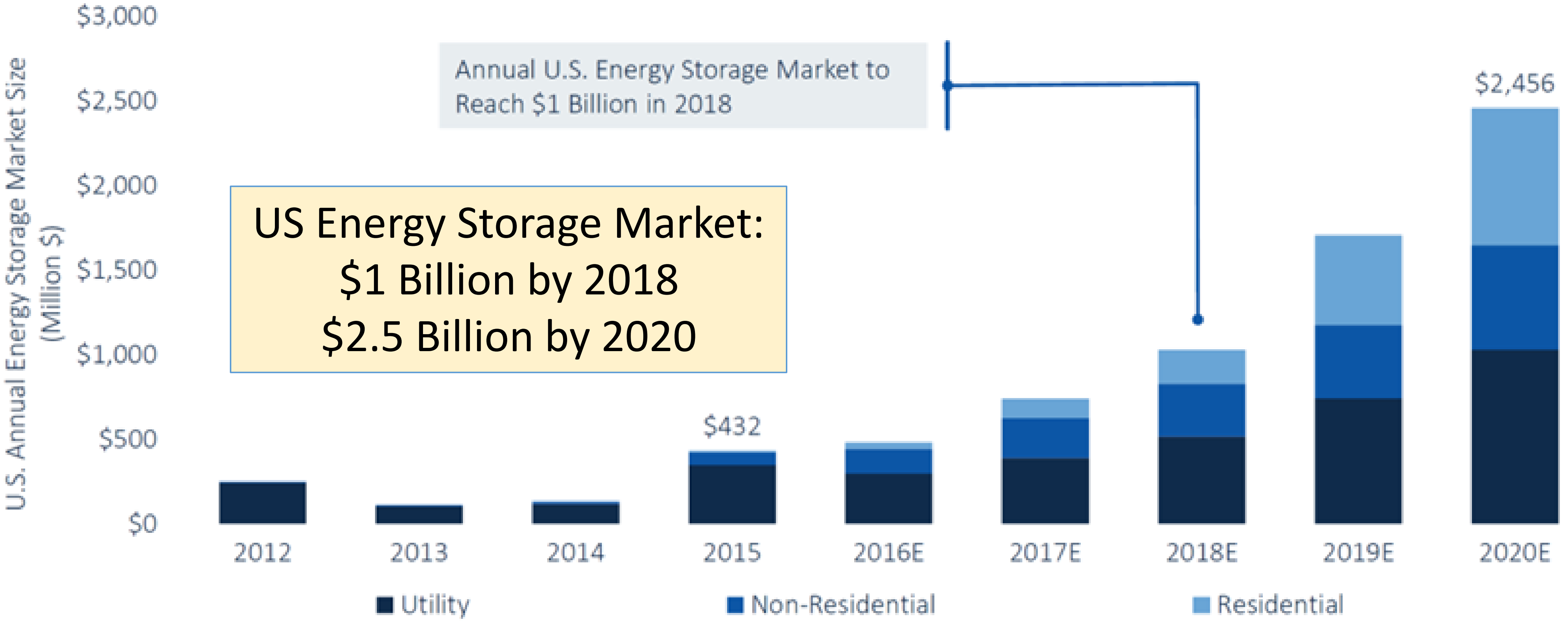
Interest in Utilizing Storage is Growing in Massachusetts but Deployment is Limited (2 MW)

	MW
Total Operational Advanced Storage	1.4
Total Announced Advanced Storage	4.4
Total Proposed Advanced Storage	8.1
Total	13.9





Opportunity to Grow MA Clean Energy Economy with Energy Storage



US Energy Storage Market:
$1 Billion by 2018
$2.5 Billion by 2020

US Market for Advanced Energy Storage technologies is expected to grow by 500% in next five years. There is a huge opportunity to expand the Commonwealth's successful clean energy industry.

Energy Storage Stakeholder Engagement

Goal: Identify high level needs and challenges for energy storage in Massachusetts

- As part of the Study, **key stakeholders** were engaged through meetings and interviews from Oct 2015 to April 2016
- Key Stakeholders Included:
  - Independent System Operator of New England (ISO-NE);
  - Investor Owned Utilities (IOUs);
  - Municipal Light Plant utilities (MLPs);
  - independent power producers;
  - renewable energy developers;
  - competitive suppliers;
  - electricity consumers and ratepayers;
  - Energy Storage technology developers;
  - System integrators

- Stakeholder workshop (Oct 2015)
  - 300 organizations contacted over 150 people attended.
  - Stakeholder breakout sessions:
    - Wholesale Markets/Transmission;
    - Utility Applications – Distribution;
    - Behind-the-Meter/Distributed Energy Resources (DER)
    - Energy Storage Technology Developers
- Follow-up Webinar (Dec 2015) and Survey (March 2016)
  - The study team conducted more detailed follow-up with certain organizations and individuals via surveys (160 responses), group webinar sessions.
- State of Charge Energy Storage Study Released
  - State of Charge energy storage study released 9/16/16
  - ESI Energy storage demonstration program approved by MassCEC Board 9/20/16
  - State of Charge study public stakeholder event 9/27/16

Energy Storage Stakeholder Perspectives

➢Stakeholders provided feedback on:

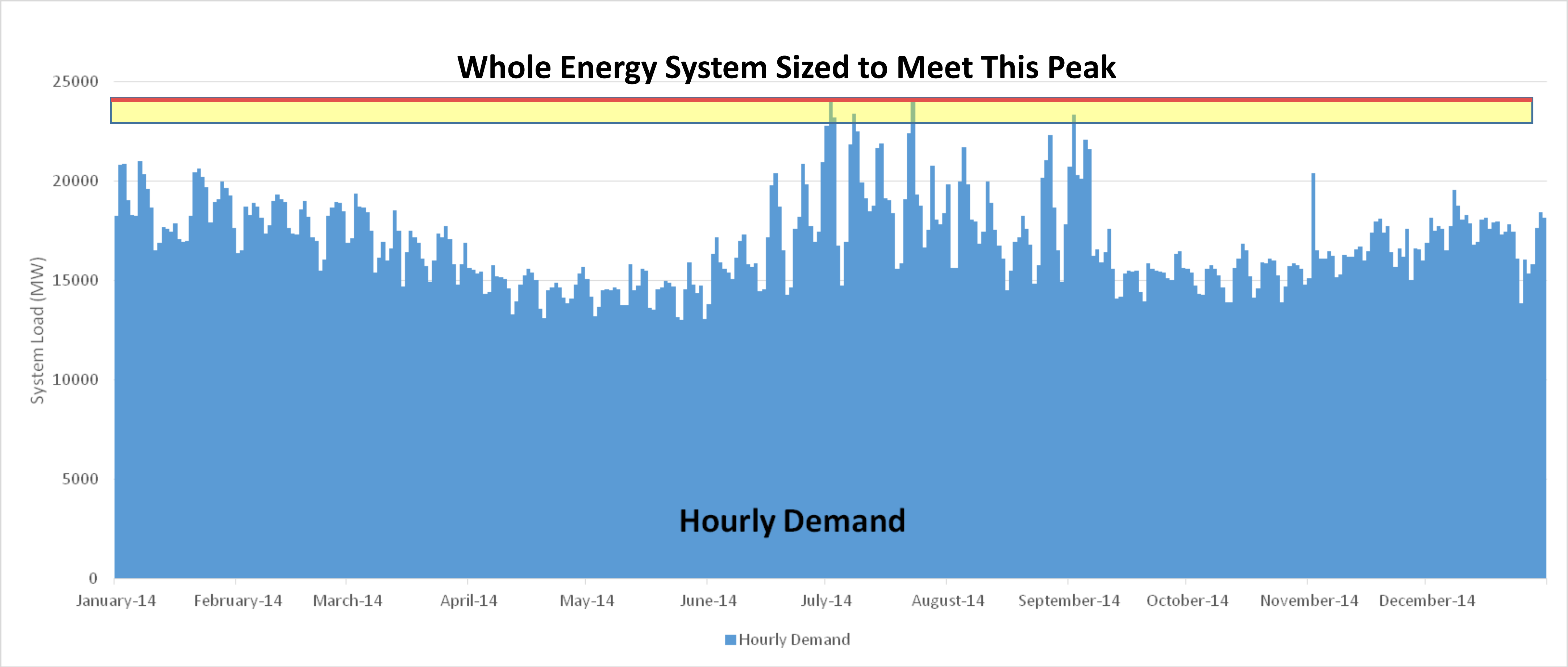
- Policy and Regulatory Challenges
- Market Barriers
- Deployment and Market Growth
- Renewable Integration
- Financing and Monetization
- Ownership Models
- Data Availability
- Locational Benefits

- The stakeholder perspectives helped shape and prioritize the modeling and use cases presented
- Further stakeholder engagement during the modeling process was utilized to refine business models

Stakeholders, including utilities, MLPs, solar developers, and competitive suppliers, expressed interest in storage as a “**game changer**” in the energy system

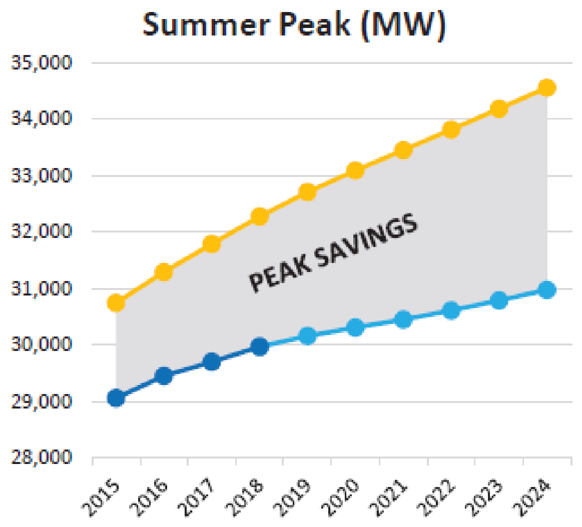
Energy Storage Can Address Massachusetts Energy Challenges

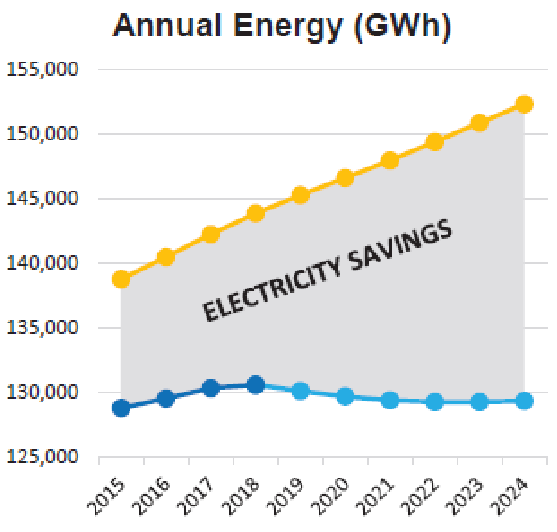
Electric Grid is Sized for Highest Hour of Demand



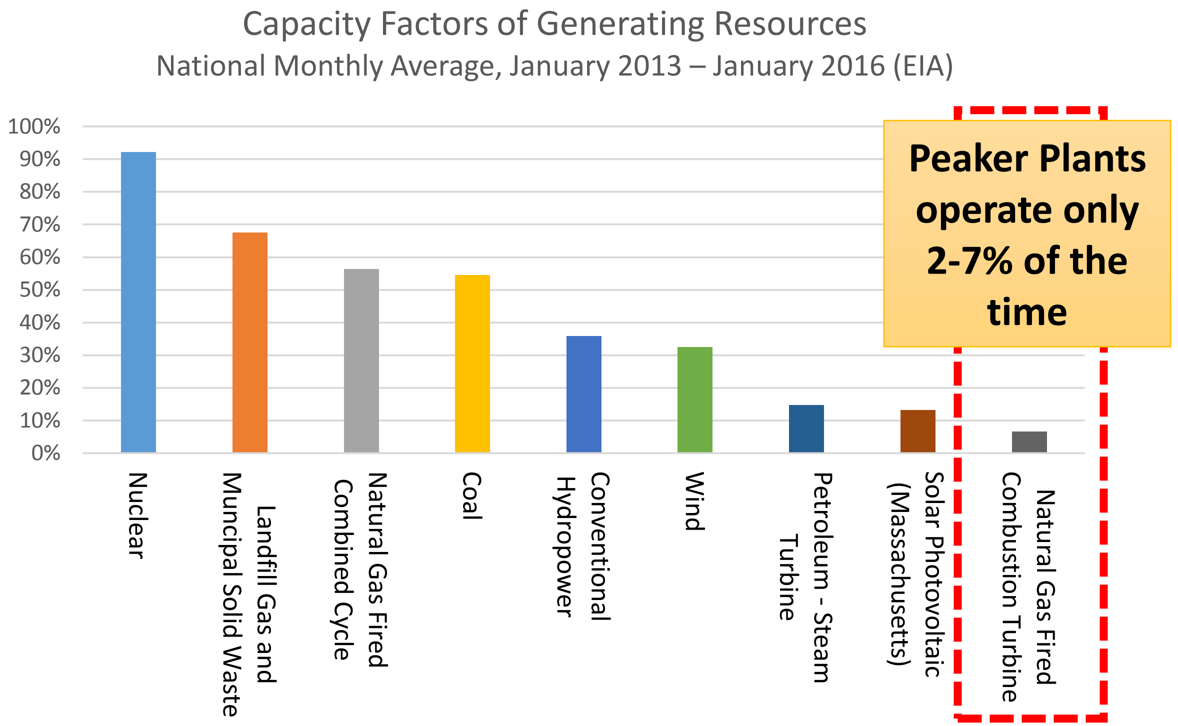
Top 1% of Hours accounts for 8% of Massachusetts Spend on Electricity
Top 10% of Hours accounts for 40% of Electricity Spend

While Energy Efficiency has Decreased Average Energy Consumption, Peak Continues to Grow (1.5% per year)



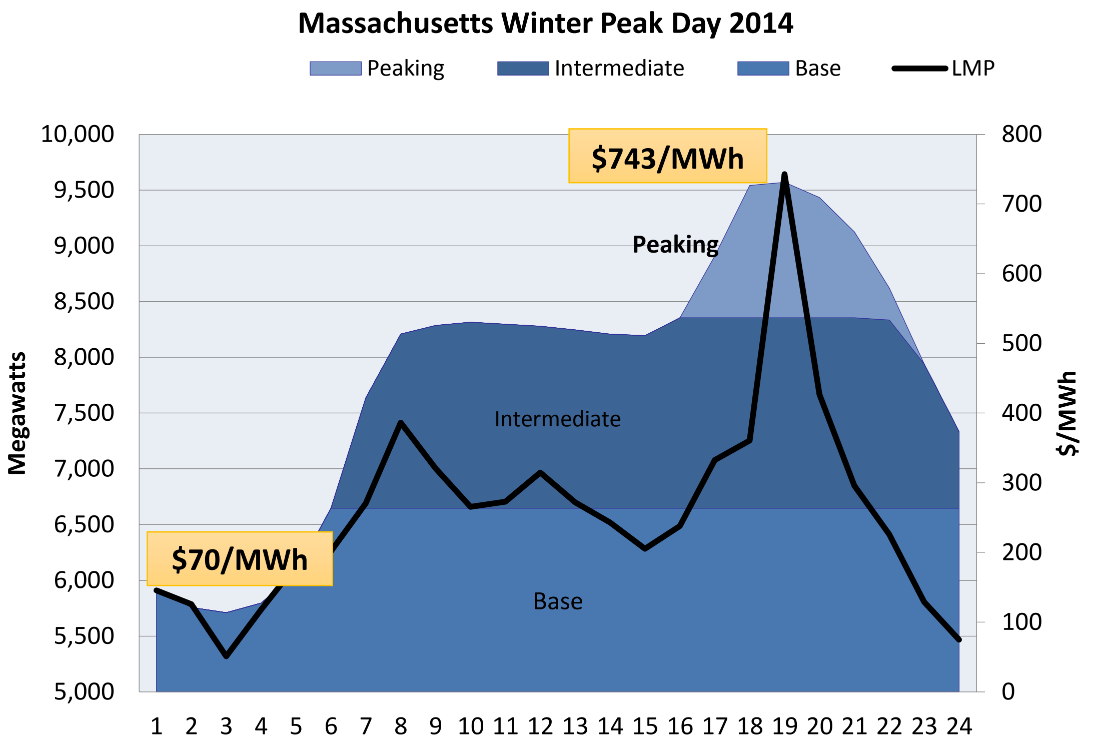


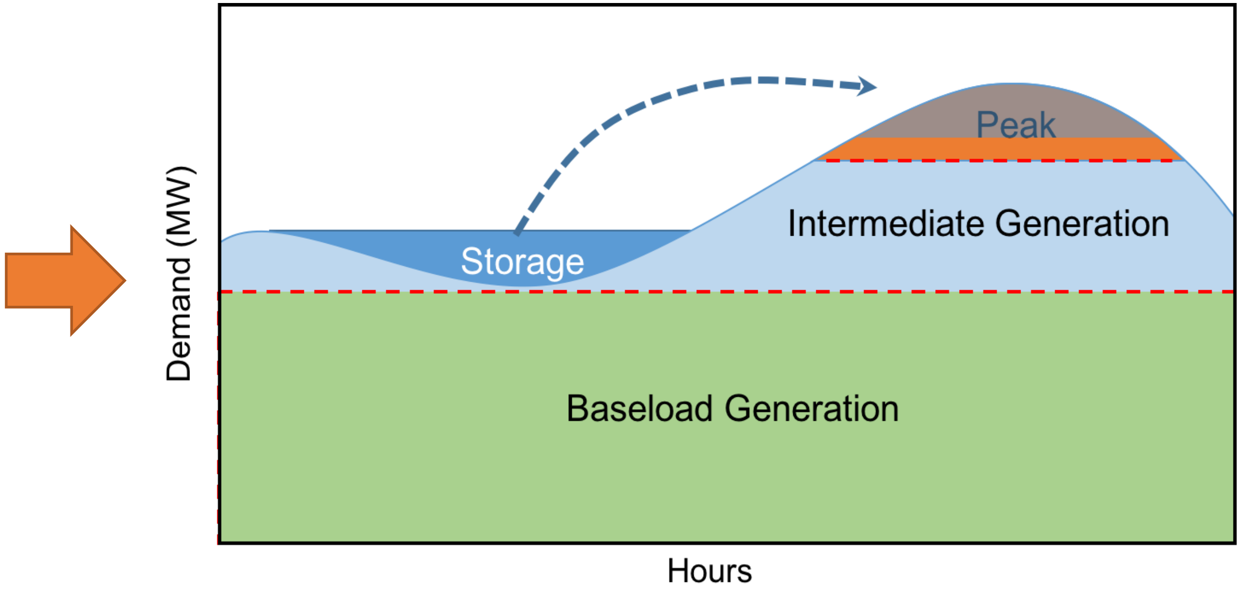
Source: ISO-NE State of the Grid- 2016



Growing peak results in inefficient use of grid assets, including generation, transmission and distribution, increasing the cost to ratepayers

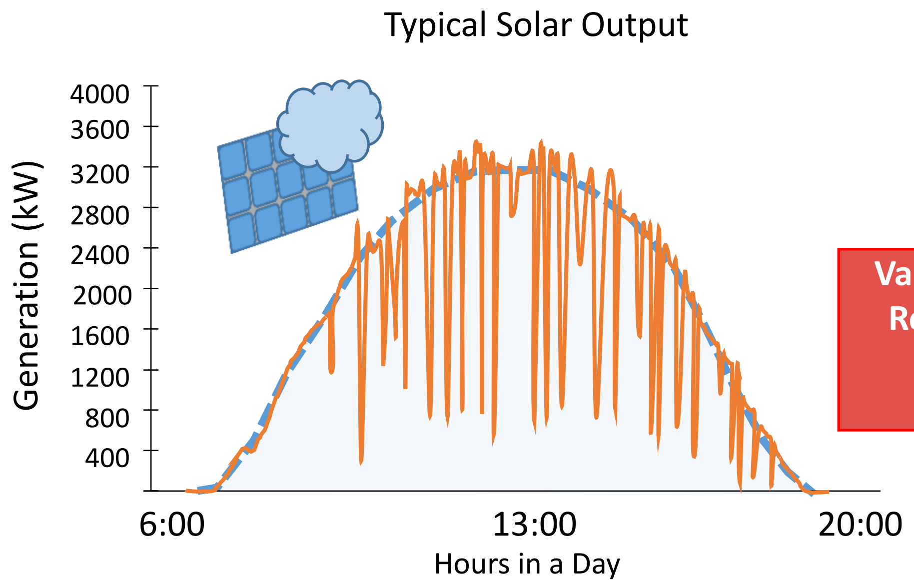
Storage is "Game Changer" for Meeting Peak





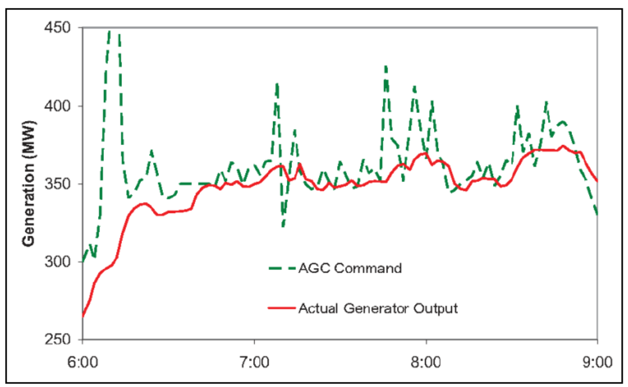
Energy storage is the only technology that can use energy generated during low cost off-peak periods to serve load during expensive peak.

Increased Renewables to Meet State GHG Goals Requires Increased Grid Flexibility to Manage Intermittency

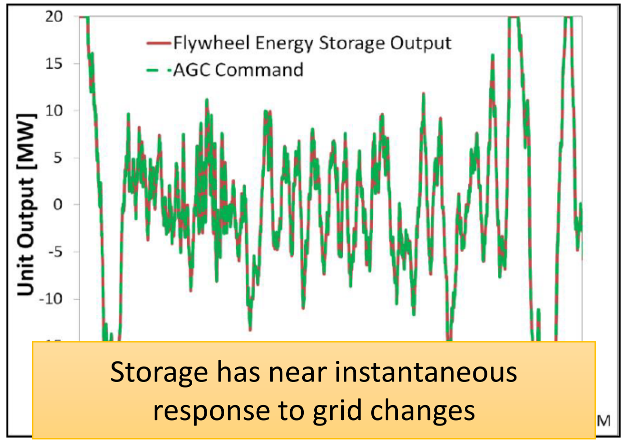


Renewable resources, such as solar, can have variable generation

Variable Output Generators Requires Fast and Flexible Resources to Maintain Balance and Reliability



Slow-ramping Generator

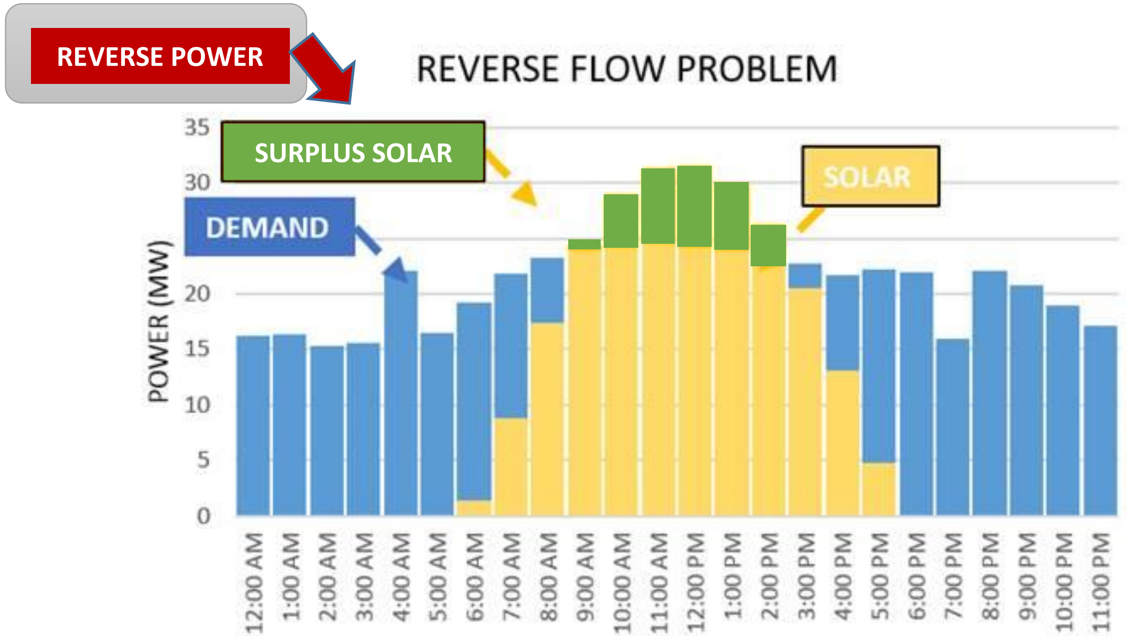


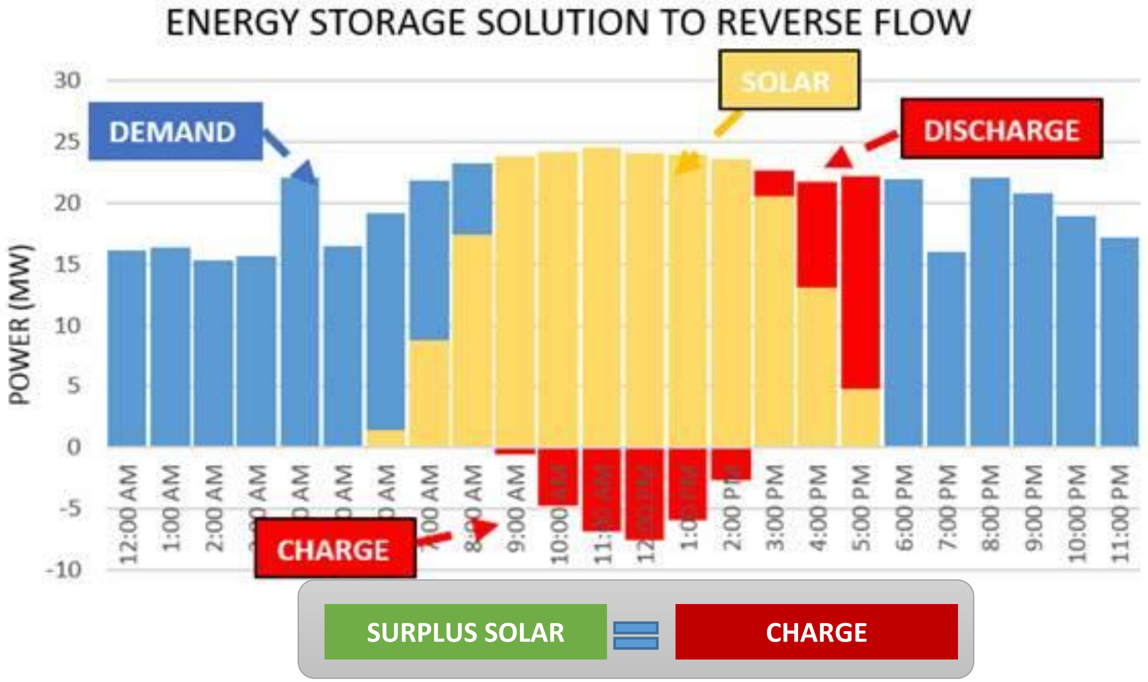
Fast-responding Energy Storage

According to ISO-NE "State of the Grid – 2016", fast and flexible resources will be needed to balance intermittent resources' variable output. Storage can provide this flexibility.

Amount of Distributed Generation has Skyrocketed

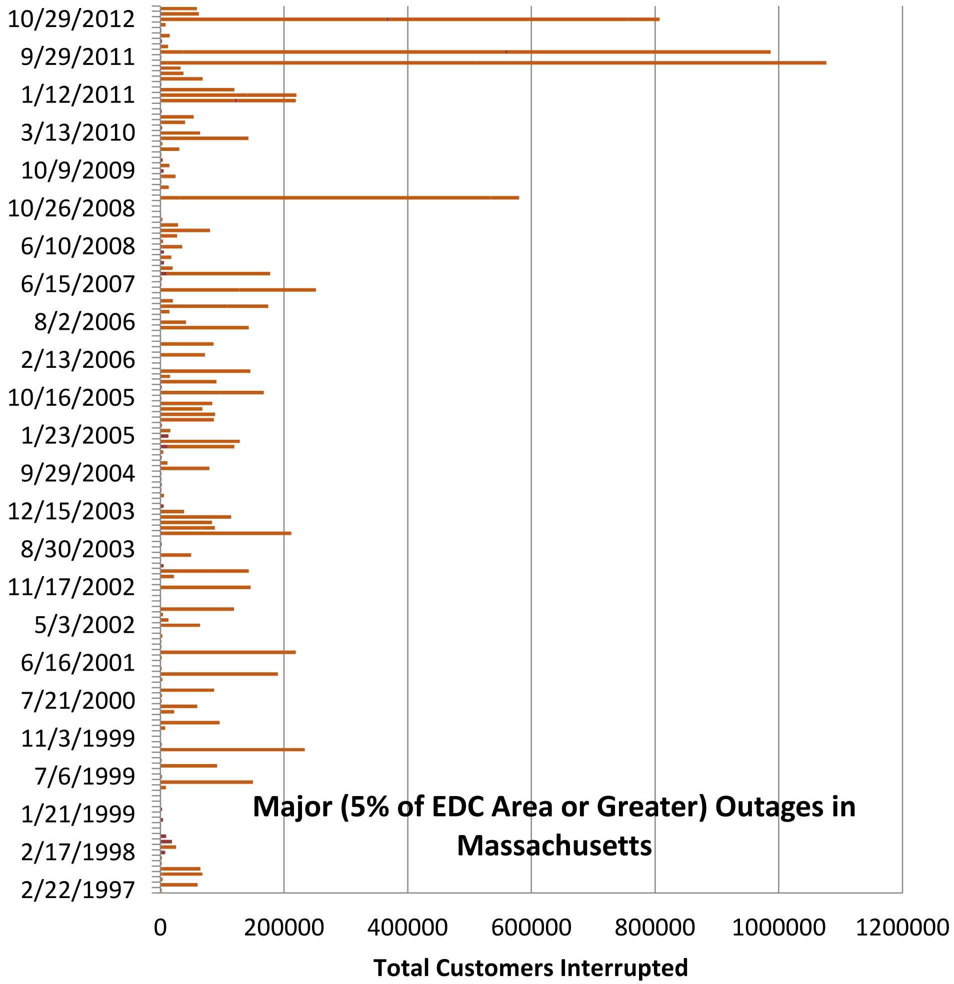
- There are over 55,000 distributed solar projects in Massachusetts
- Distributed generation is growing at rate of 500 installed projects per week





As distributed generation increases, utilities are challenged to manage reverse power flow at substations. Distributed storage can manage and optimize power flows.

Major Outages From Storm Events are More Common

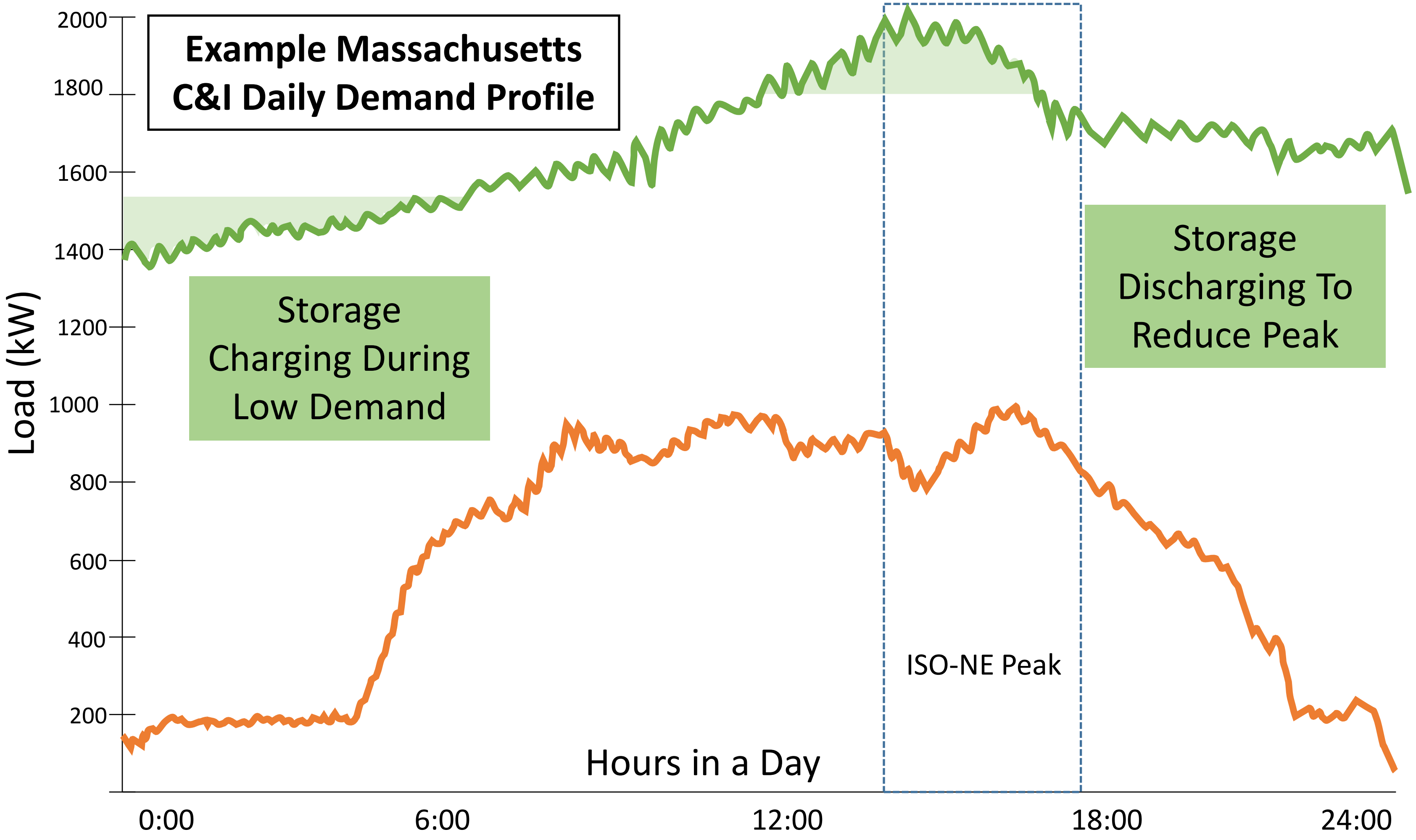


2/8/2013	February Nor'easter ("Nemo")
10/29/2012	Hurricane Sandy
10/29/2011	2011 Halloween Nor'easter
8/28/2011	Hurricane Irene
1/12/2011	January 2011 Blizzard
12/26/2010	December 2010 Blizzard
12/11/2008	2008 December Ice Storm
4/15/2007	April 15 Rain Storm
6/30/2001	June 30 Wind Storm
9/16/1999	Hurricane Floyd

- Although total weather days have decreased, the number of customer outages have increased due to an increase in severe storm events
- Major storm events **increase costs for the utilities** to maintain resiliency

Storage, especially when integrated with microgrids, can increase resiliency in storm events

High Electricity Costs Impact Massachusetts Businesses



- Massachusetts has one of the highest electricity rates in the nation
- Commercial electricity customers pay utility demand charges based on customer's peak hour

Massachusetts businesses, especially those with high electricity use, could use storage to better manage their peak and reduce electricity costs

Energy Storage Opportunity Analysis

Alevo Analytics Modeling

23

Storage In Commodity Supply Chains

FOOD

Warehouses
Grocery stores
Freezers & refrigerators

WATER

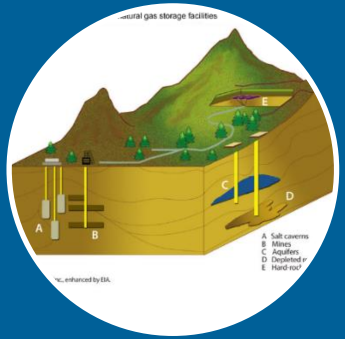
Reservoirs
Above-ground tanks
Water bottles

GASOLINE

Underground tanks
Above-ground tanks
Tank trucks
Portable fuel tanks

OIL

Above-ground tanks
Piping



NATURAL GAS

Depleted fields
Aquifers
Salt caverns
Pipelines
Above-ground tanks

Storage capacity more than 10% of daily consumption

ELECTRICITY

Energy Storage Technologies

Currently less than 1% of daily electricity consumption for MA

The electricity market has a fast "speed of light" supply chain and the least amount of storage. This lack of storage creates a need for additional infrastructure to maintain market reliability.

Advanced Energy Storage Capacity Optimization

- Minimization of wholesale market costs and capacity cost
- Minimization of Massachusetts emissions
- Increased utilization of transmission and distribution assets
- Minimization of incremental new transmission assets
- Increasing resiliency with wide scale transmission, distribution, and generation outages
- Minimization of requirements for peaking power plant
- Stress testing with varying levels of power demand, fuel price, and renewable deployment

Advanced Storage Optimization Model

Model Details

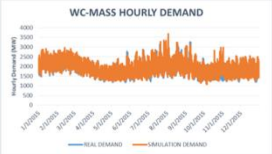
- Generators
- Nodes
- Trans. Lines
- Transformer
- Renewables

Uncertainties

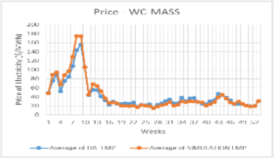
- Load Growth
- Fuel Prices
- Regional System Plan
- Renewable Availability

BENCHMARK

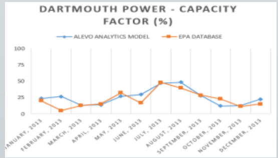
Demand



Price



Cap. Factor



Gen. Cap.

Emission

CAPACITY OPTIMIZATION

Storage Technology Categories

- Long Duration
- Medium-Long Duration
- Medium-Short Duration
- Short Duration
- Where?
- How much?
- When?

PRODUCTION COST MODEL

- Hourly Day-ahead Market
- Sub-hourly Real-time Market

Storage bring efficiency to Day-Ahead and Real Time markets and simultaneously advantages to distribution, transmission and generation.

STORAGE PROGRAM

Evaluation

- MA Ratepayer Benefits
- Emission
- Reliability
- Renewable Integration
- Reserves
- Peak Demand
- Use Cases
- T&D Deferral
- ISO-NE Production Cost

Optimization Of Advanced Storage

1. Candidate Electrical Locations: 250
2. Nodal Power Systems Model
3. Transmission Line Max Limits
4. Solar & Wind Availability
5. Demand forecast

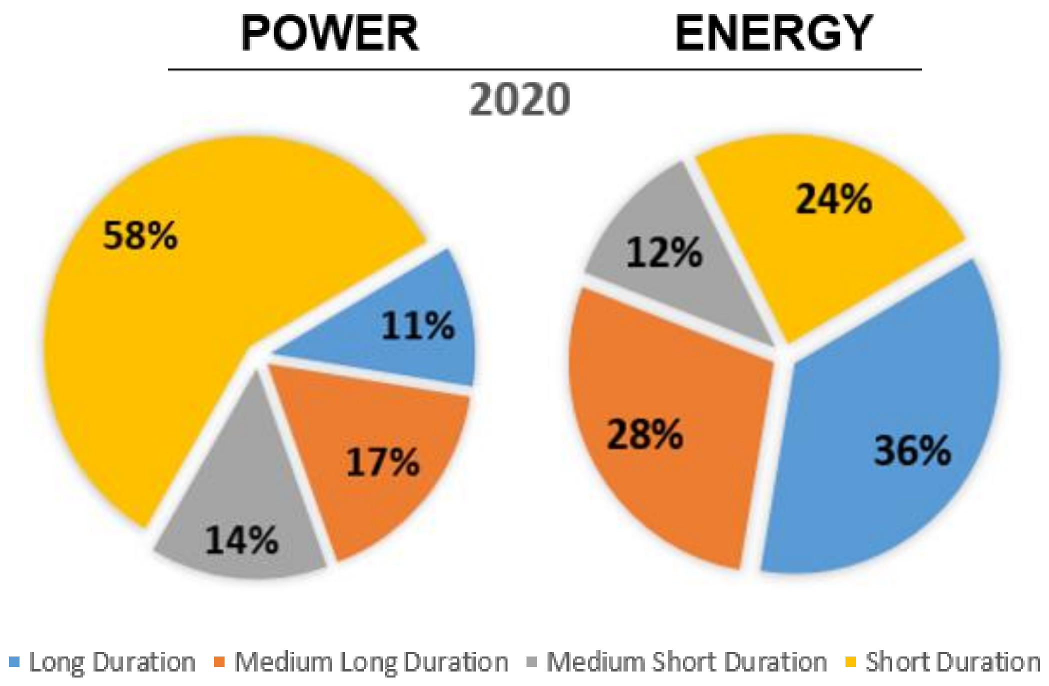
Optimization
Identifies the Optimal Storage Locations

78 Electrical locations for deployment
Deployments vary between 4 and 74 MW

Locations of Optimized Energy Storage Installations

Storage Technology Category

Storage Technology Category	Duration at Full Power	Examples
Long Duration	4+ Hours	CAES, Flow Battery, NaS Battery, Pumped Storage, Thermal Storage, Liquid Metal Battery
Medium-Long Duration	2 Hours	Lithium Ion, Flow Battery, NaS Battery, $NaNiCL_2$ Battery, Advanced Lead Acid
Medium-Short Duration	1 Hour	Lead Acid, Lithium Ion, NiCd, and NiMH Batteries
Short Duration	30 Minutes	Lithium Ion Battery, Flywheel, High Power Supercapacitors



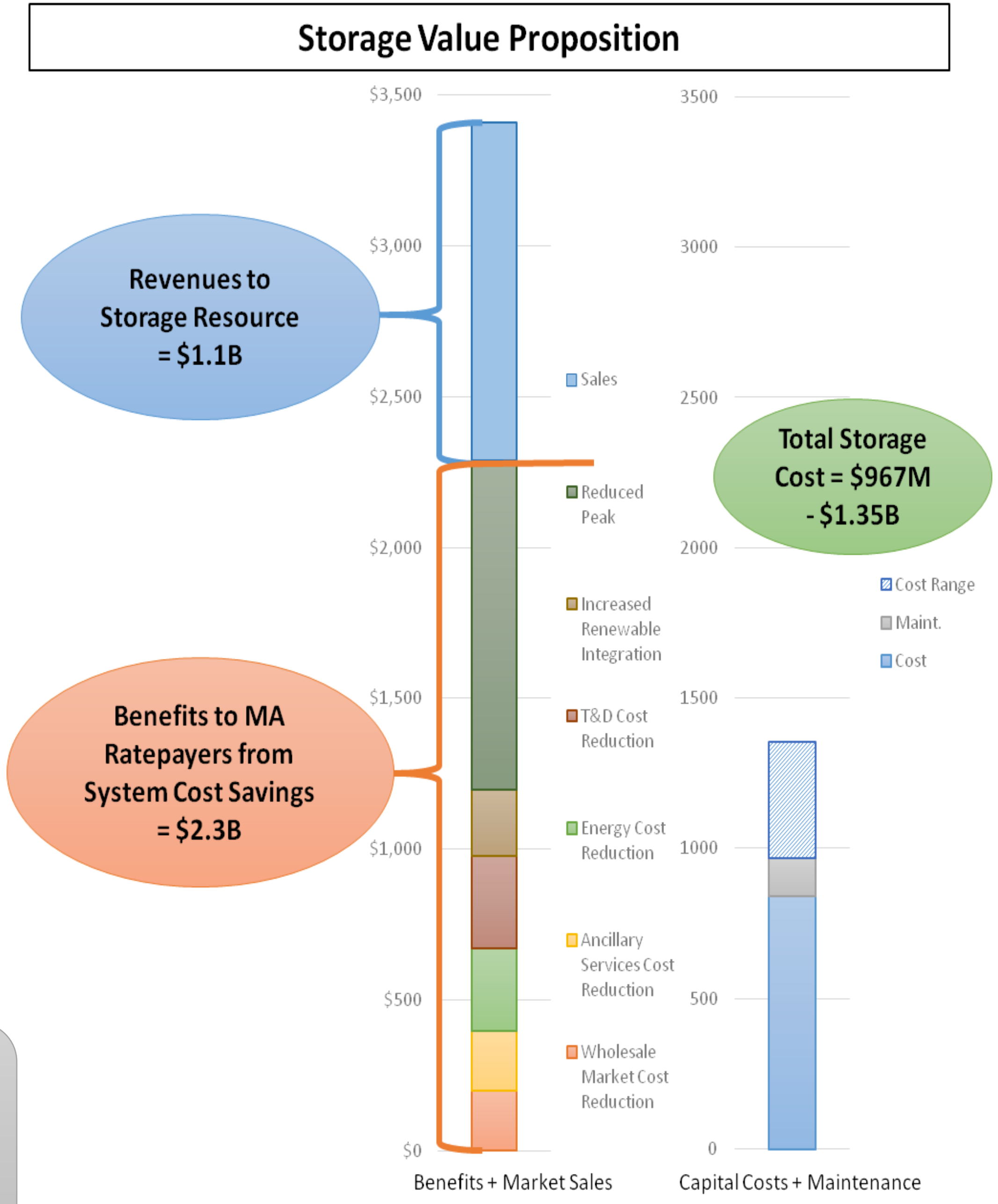
Short Duration High Power Storage = Lower Cost, Higher Flexibility

Energy duration can be extended by lowering power output, but power cannot exceed rated output

Storage Value Proposition

- Total 10 Year Value: **$3.4 billion** to Massachusetts
  - **$2.3 billion in system benefits**
    - Energy Cost Reduction
    - Reduced Peak Demand
    - Ancillary Services Cost Reduction
    - Wholesale Market Cost Reduction
    - T&D Cost Reduction
    - Increased Renewable Integration
  - **$1.1 billion** in potential market revenue to the developer
- Additional **$250 million** in additional regional system benefits, yielding consistently lower annual average energy price across all ISO-NE zones.
- Almost **10%** in Massachusetts **peak demand reduction**
- **Reduction** in CO_2 gas emissions of over **1MMTCO$_2$e**

Model Result: 1766 MW would optimize system benefits to ratepayers



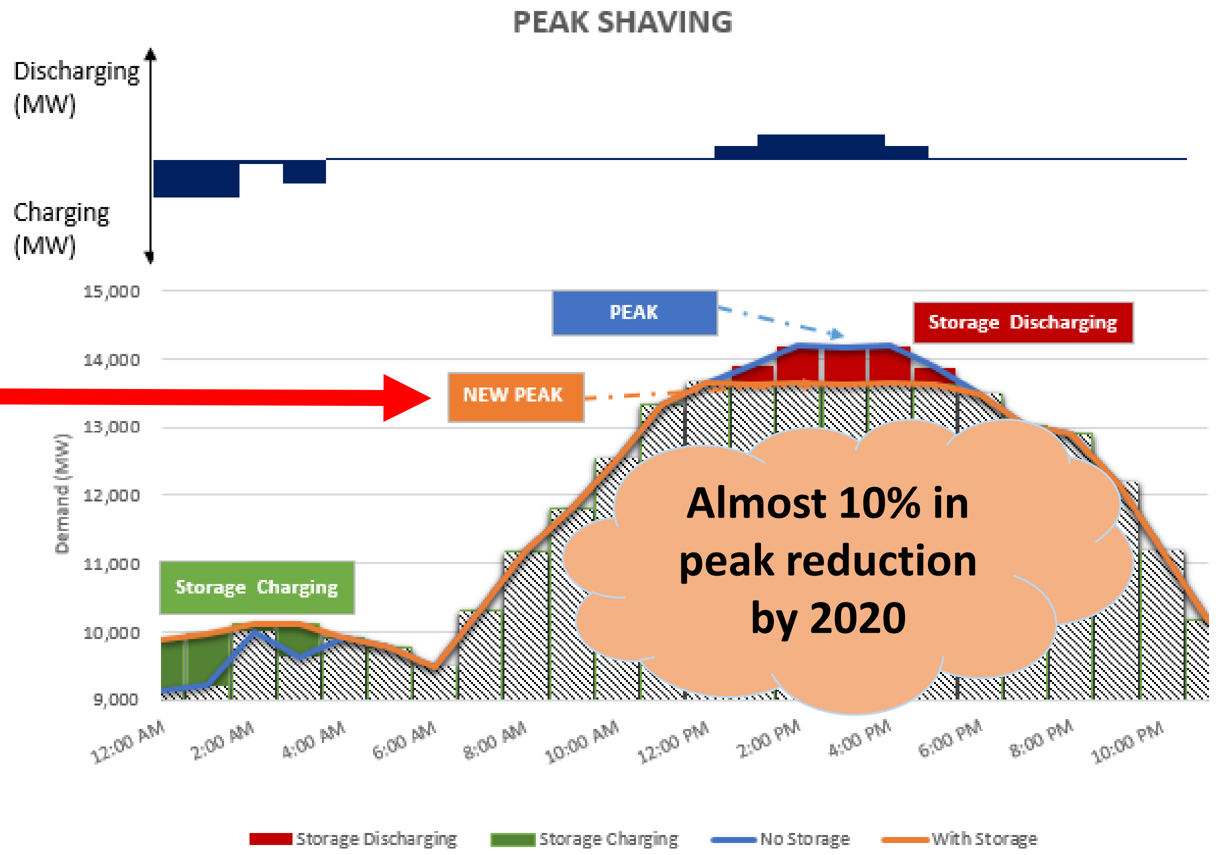
System Benefits

Benefit Categories	Benefit Description	
Energy Cost Reduction	Energy storage replaces the use of inefficient generators at peak times causing: 1) reduced peak prices which 2) reduces the overall average energy price. This also benefits the natural gas supply infrastructure.	$275M
Reduced Peak	Energy storage can provide peaking capacity to 1) defer the capital costs peaker plants and 2) reduced cost in the the capacity market	$1093M
Ancillary Services Cost Reduction	Energy storage would reduce the overall costs of ancillary services required by the grid system through: 1) frequency regulation, 2) spinning reserve, and 3) voltage stabilization	$200M
Wholesale Market Cost Reduction	Energy storage can be a flexible and rapid tool that help generators operate more efficiently through: 1) less wear and tear, 2) less start up and shut down costs, and 3) reduced GHG emissions.	$197M
T&D Cost Reduction	Energy storage 1) reduces the losses and maintenance of system, 2) provides reactive power support, 3) increases resilience, and 4) defers investment	$305M
Increased Renewable Integration	Energy storage reduces cost in integrating renewable energy by 1) addressing reverse power flow and 2) avoiding feeder upgrades	$219M
Total System Benefits		$2,288M

Storage Peak Reduction

Year	Peak Demand for Base Case (MW)	Peak Demand for Energy Storage Case (MW)	Delta in Peak Demand (MW)	% Reduction in Peak Demand
2019	8,828	8,119	709	8.04%
2020	9,293	8,385	908	9.77%

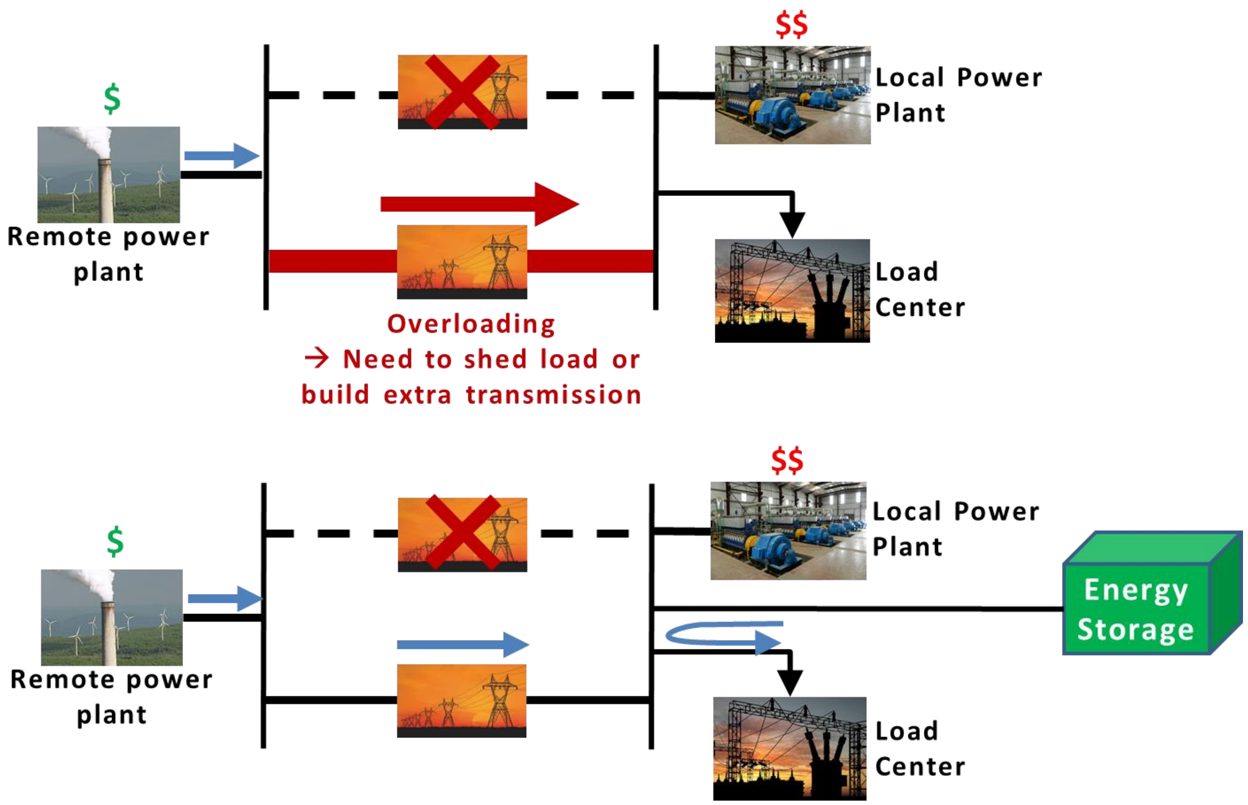
Total Savings (thousand $)	Capital Cost	2017	2018	2019	2020
Natural Gas Conventional Combustion Turbine	973$/kW	137,193	392,119	689,857	883,484
Natural Gas Advanced Combustion Turbine	676$/kW	95,316	272,428	479,284	613,808



- Storage dispatched on peak days to get maximum peak shaving.
- Reduction of the peak can reduce the need for additional peaker resources and avoid capital costs

$1093 million peaking plant cost reduction over 10 years.

Storage Provide Critical Power System Reliability

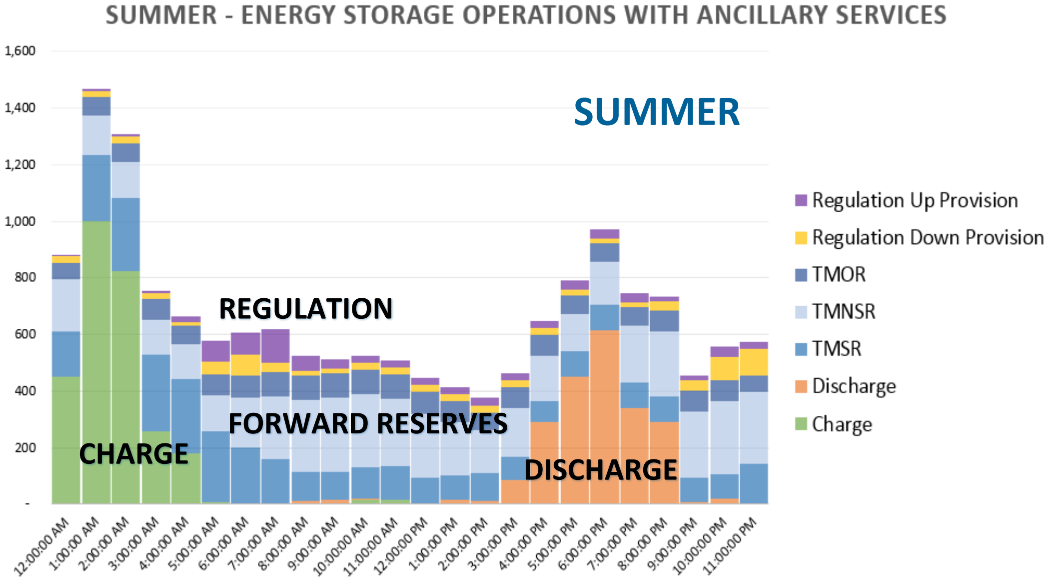


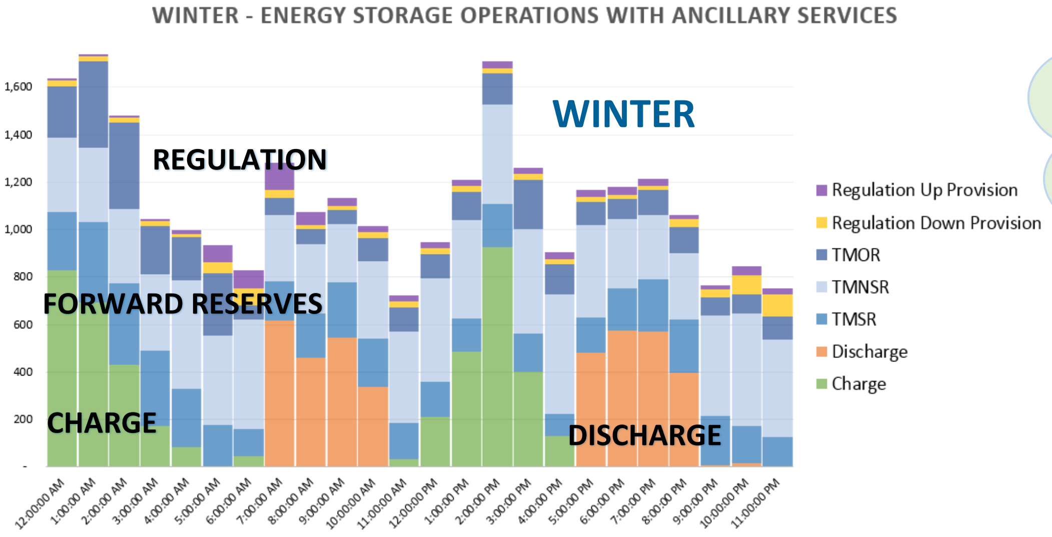
- Energy Storage can provide real and reactive power support to help eliminate voltage violations and solve power flow non-convergence and save millions of dollars for the transmission upgrade needs .
- ISO-NE time-sensitive transmission needs:
  - 36 time-sensitive voltage violations on elements at or below 115kV
  - 12 time-sensitive non-convergence power flow problems
- ISO-NE non-time-intensive voltage needs

Storage provides flexibility in how the system can respond to transmission outage conditions, avoiding overloading the transmission line

Part of the $275 million energy cost and $305 million T&D cost reduction over 10 years.

Reserve Service Provision By Energy Storage



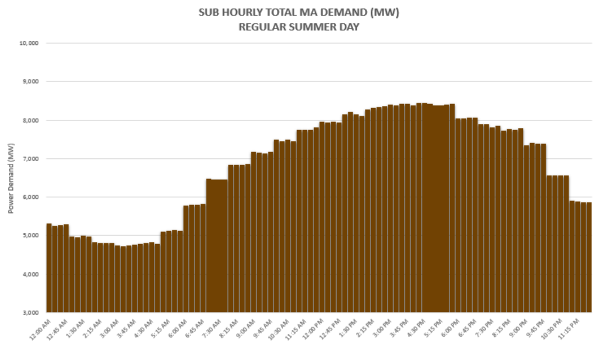


- Energy storage units can provide ancillary services at lower cost
  - Energy storage can charge when energy cost is lower
  - No start cost and operation cost for energy storage

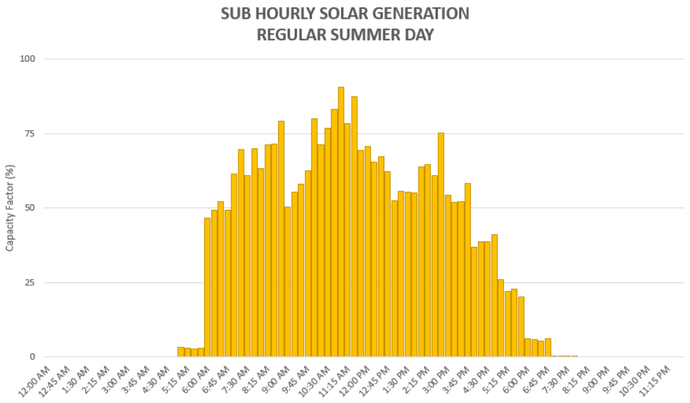
$200 million ancillary services cost reduction over 10 years.

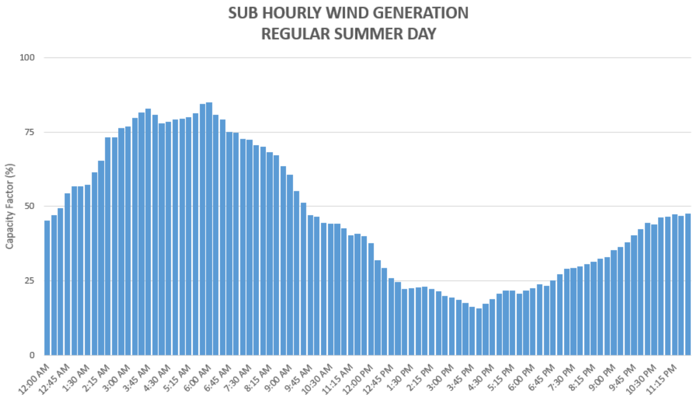
*ISO market rules need to be updated to enable advanced energy storage to participate with other dispatchable generation in the system to achieve system benefits.

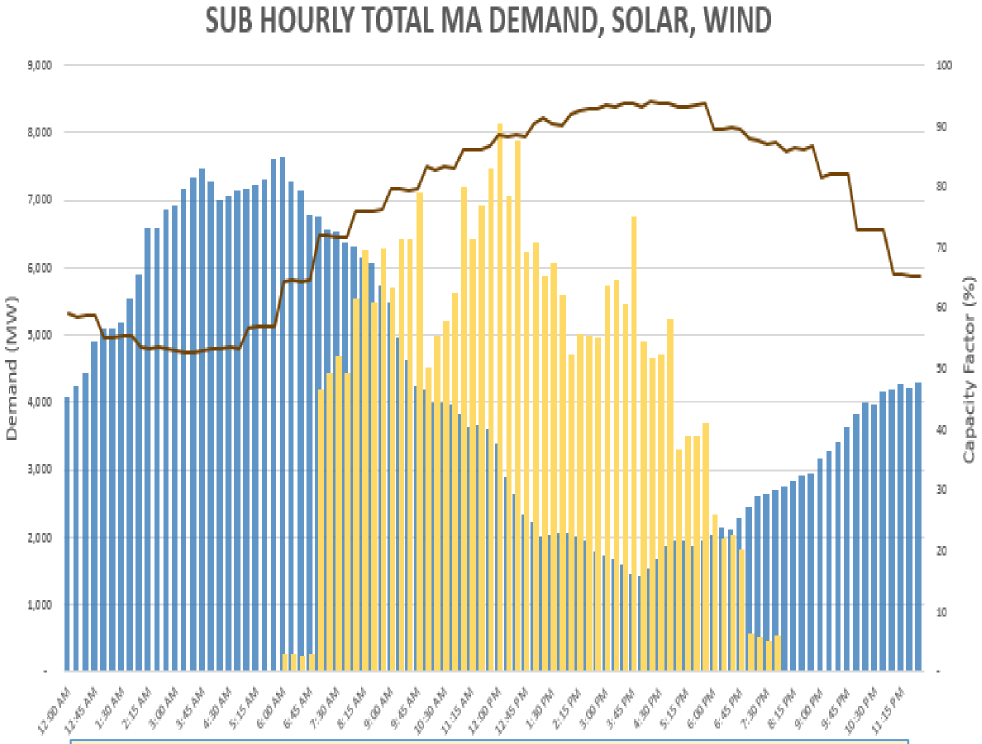
Energy Storage Helps Renewable Integration



SOLAR + DEMAND + WIND



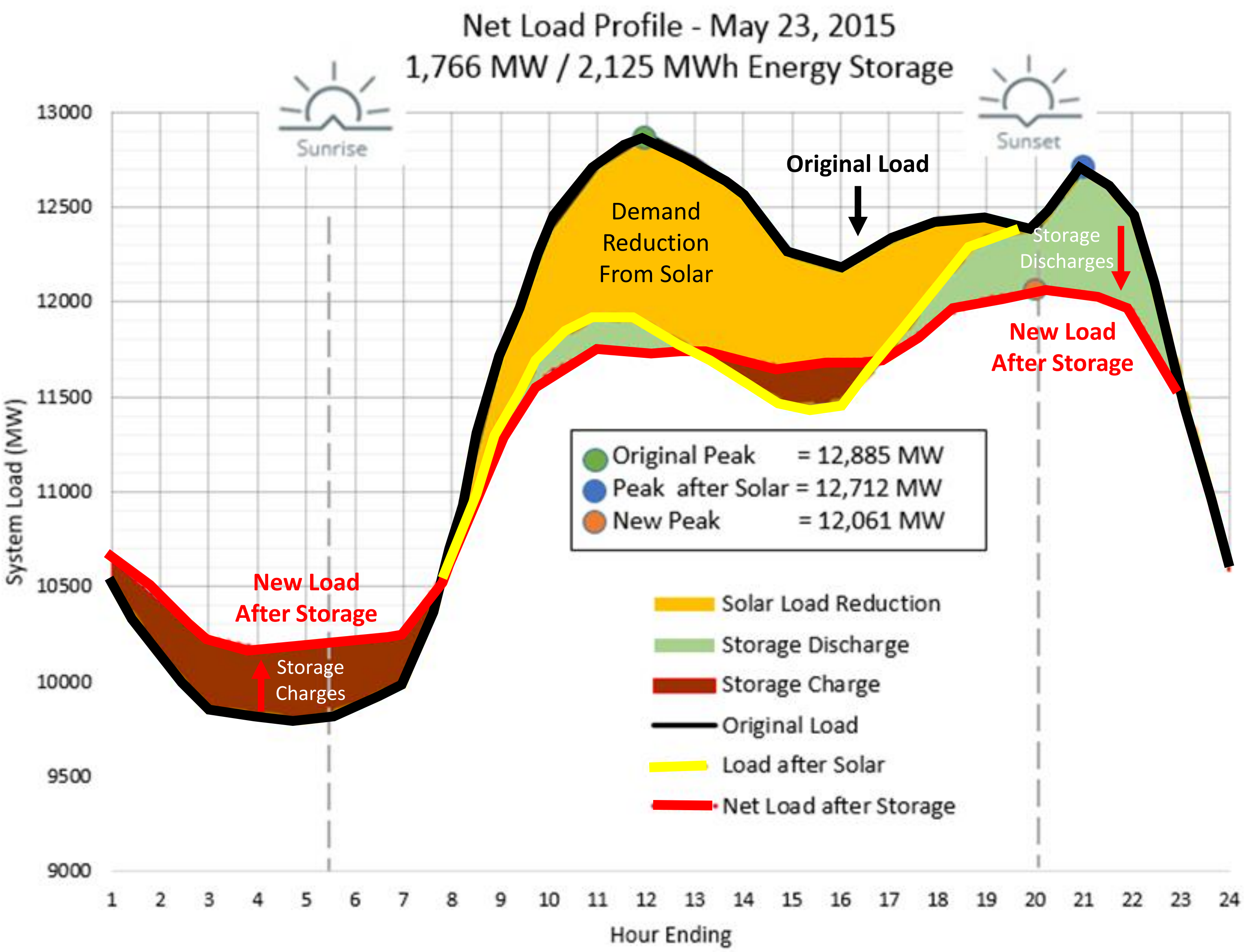




Wind and solar profile does not match up with demand shape

Energy storage can charge at low demand with cheap renewable energy and discharge at high demand period when energy cost is high.

Time Shift Of Renewables And Peak Reduction

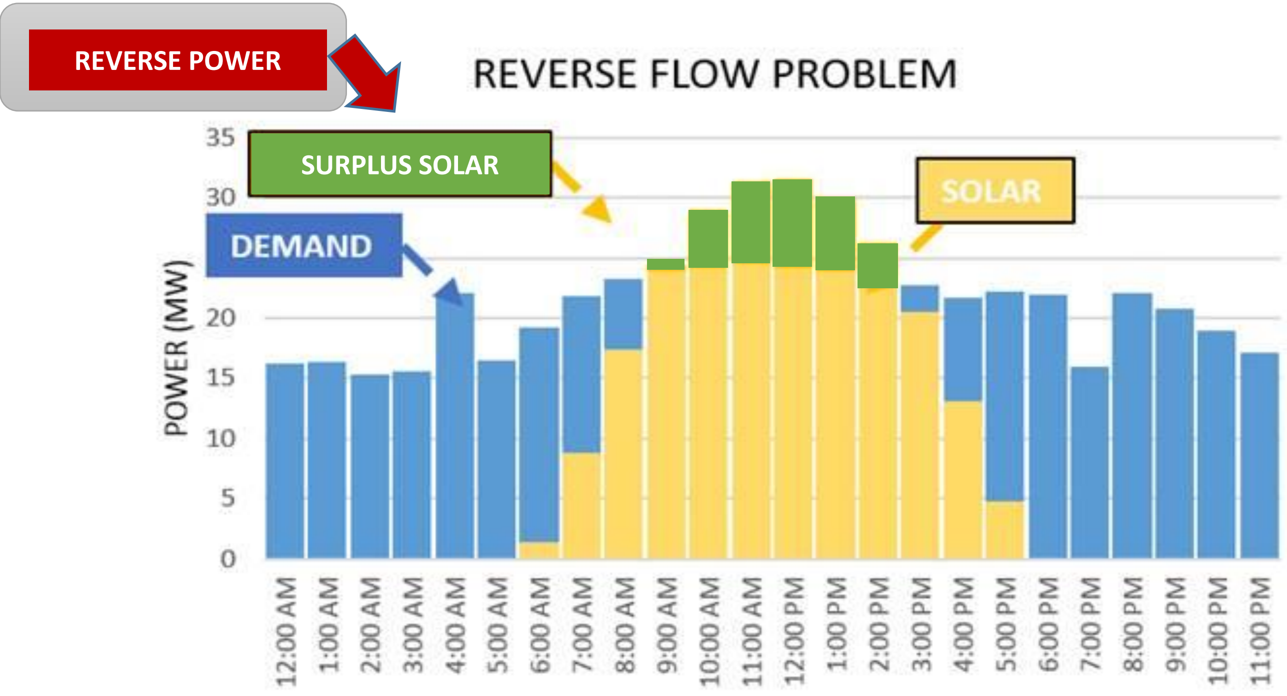


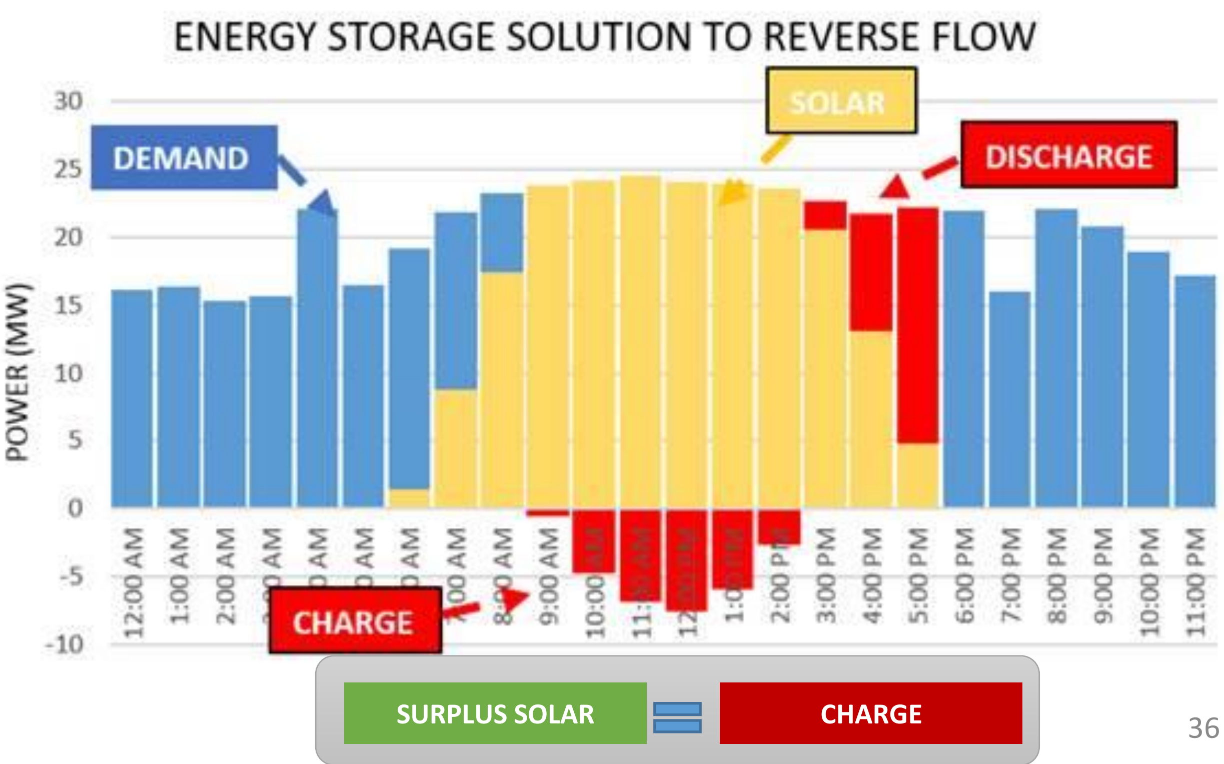
$219 million increased renewable integration savings over 10 years.

- Solar reduces system peak and storage can provide additional peak reduction after sunset
- Time shift of renewables
- Relieving distribution constraints
- Helps meeting the state’s current solar target

Reverse Flow Problem With Solar Integration

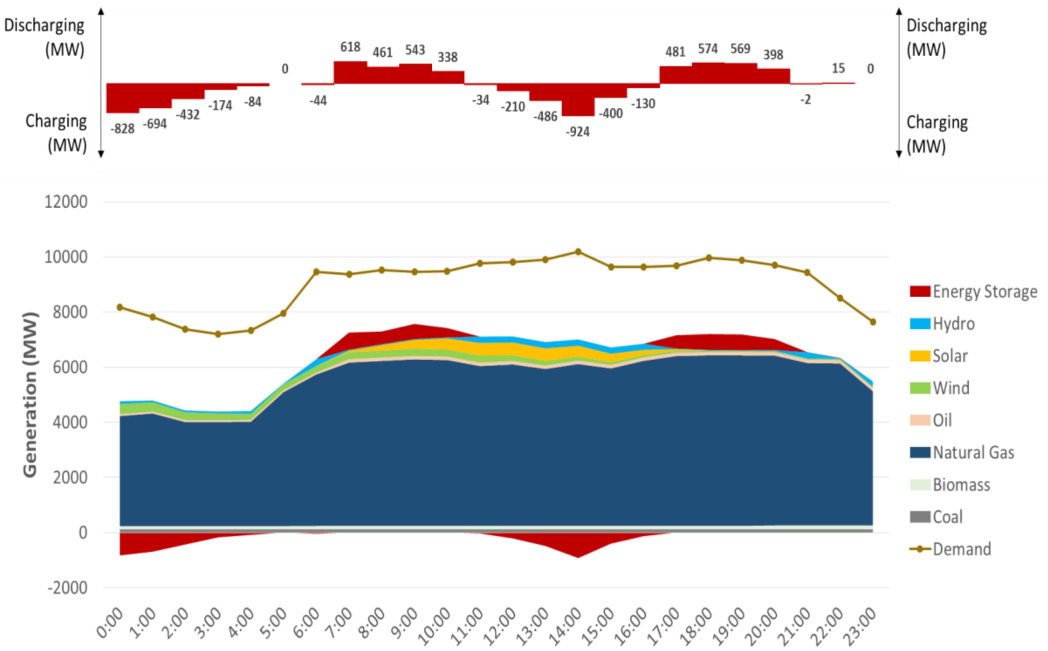
- Reverse flow may occur during times of light load and high PV generation.
- Protection systems are NOT designed for it.
- Storage charge using the solar surplus, and discharge during high demand , achieve both renewable and peaking benefit.
- Also, mitigates light loading transient instability happening at the transmission level



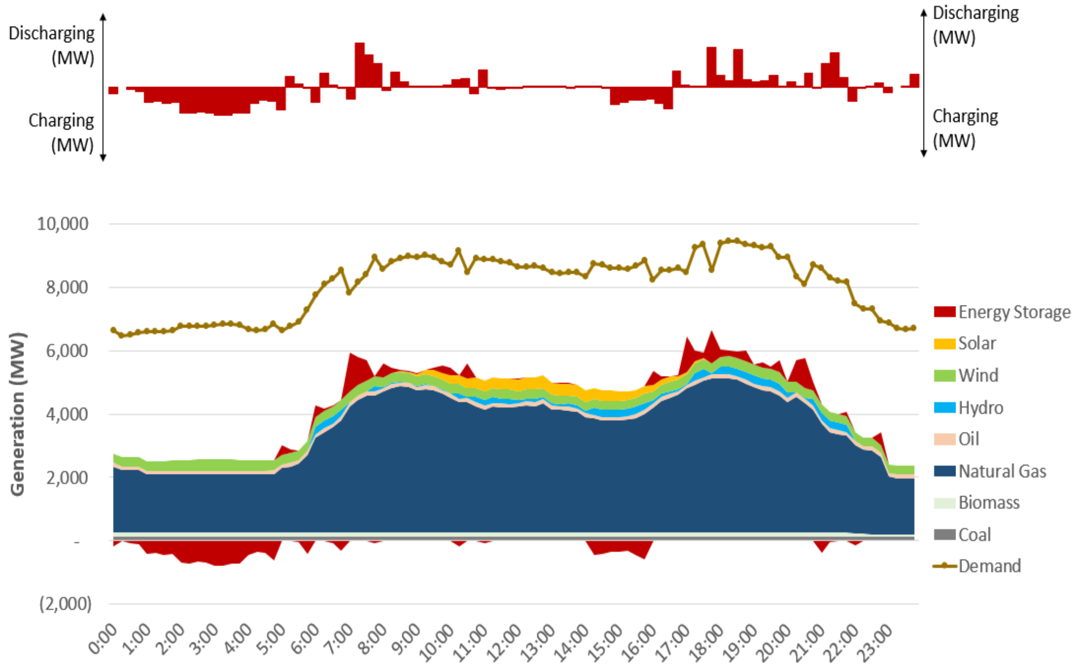


Flexible Capacity To Integrate More Renewable

- Day-ahead Hourly

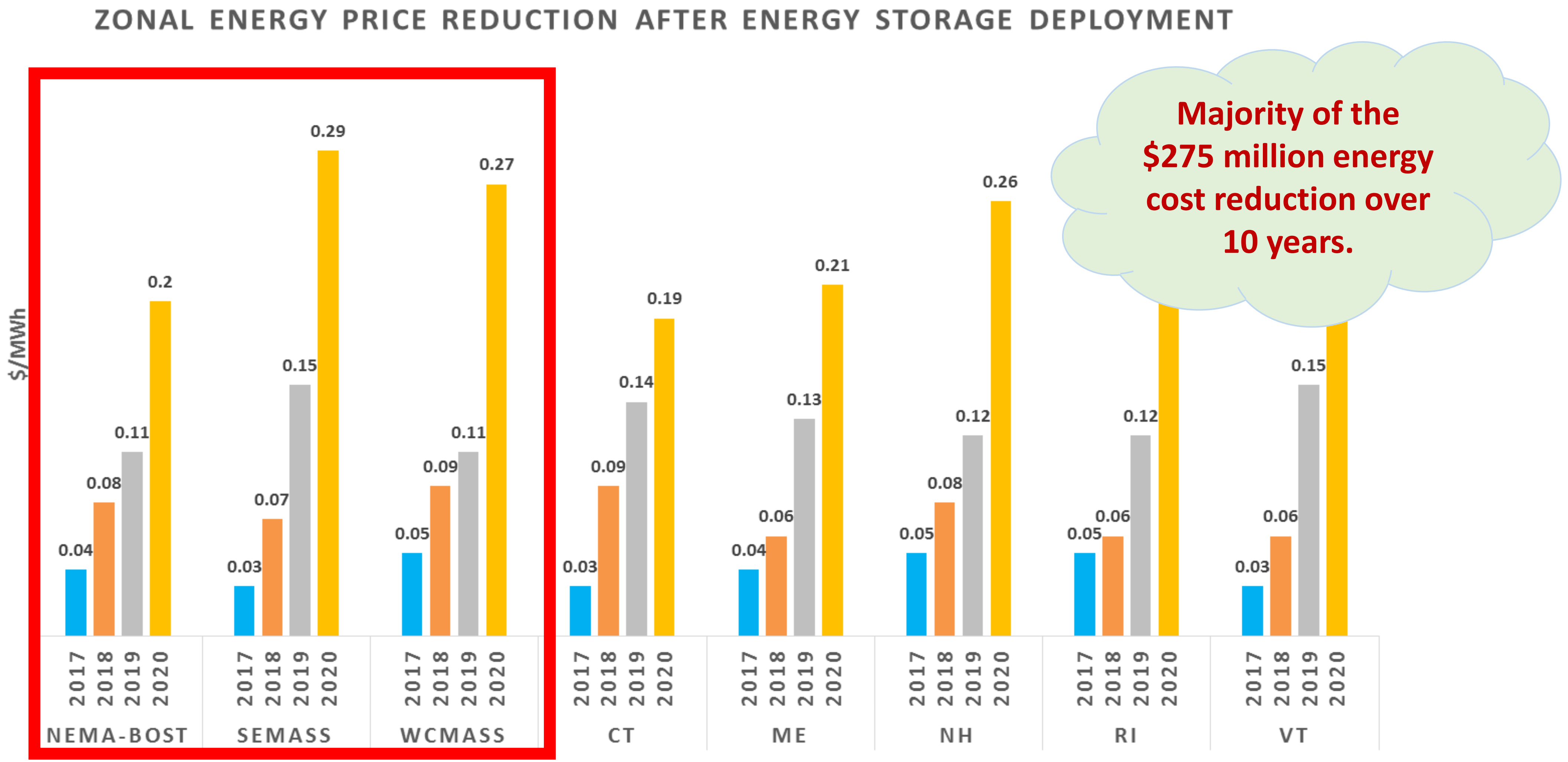


- Real-time Sub-hourly



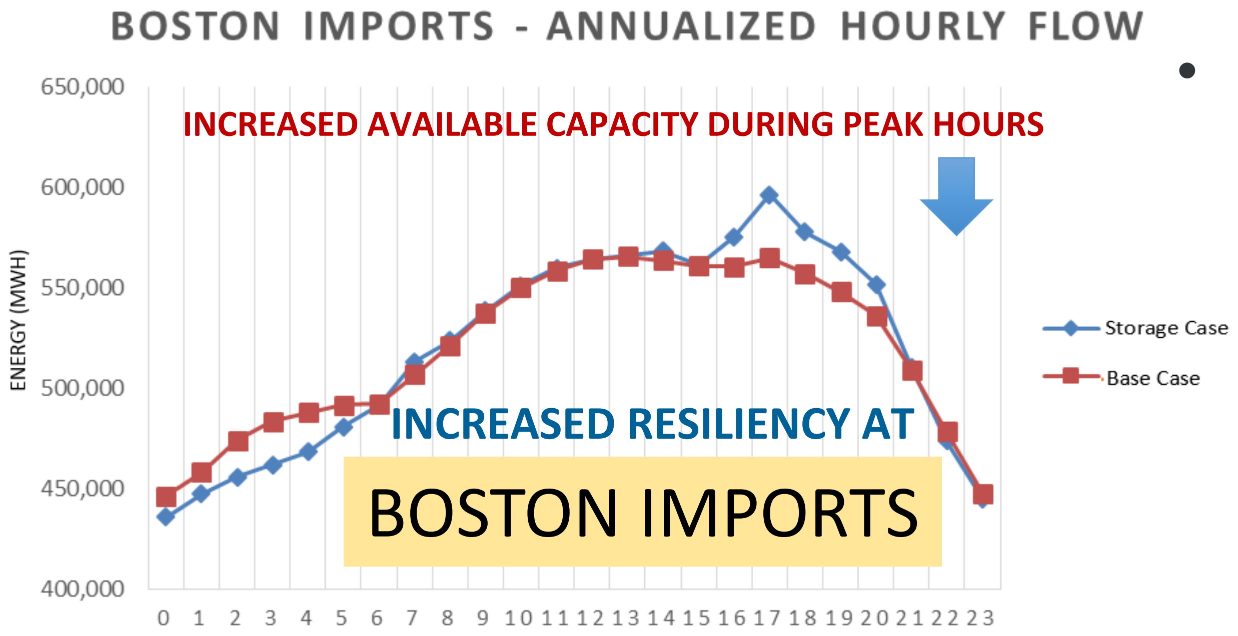
- Energy storage allows more efficient market operations because it can charge at low energy cost and discharge at high energy cost.
- Energy storage provides the ability to integrate more renewable with its fast response to intermittency.
- Energy storage gives the system more flexibility to respond to forecast error, avoiding uplift cost.

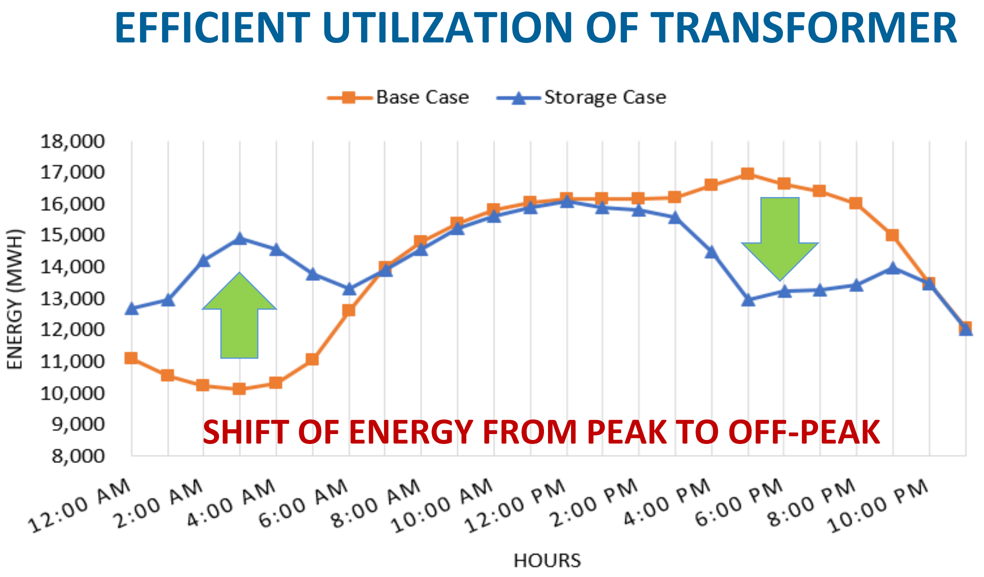
Price Of Electricity Reduction



Time shift of energy by storage yields consistently lower annual average energy price than base case across all ISO-NE zones and years

Deferral and Utilization of T&D Assets

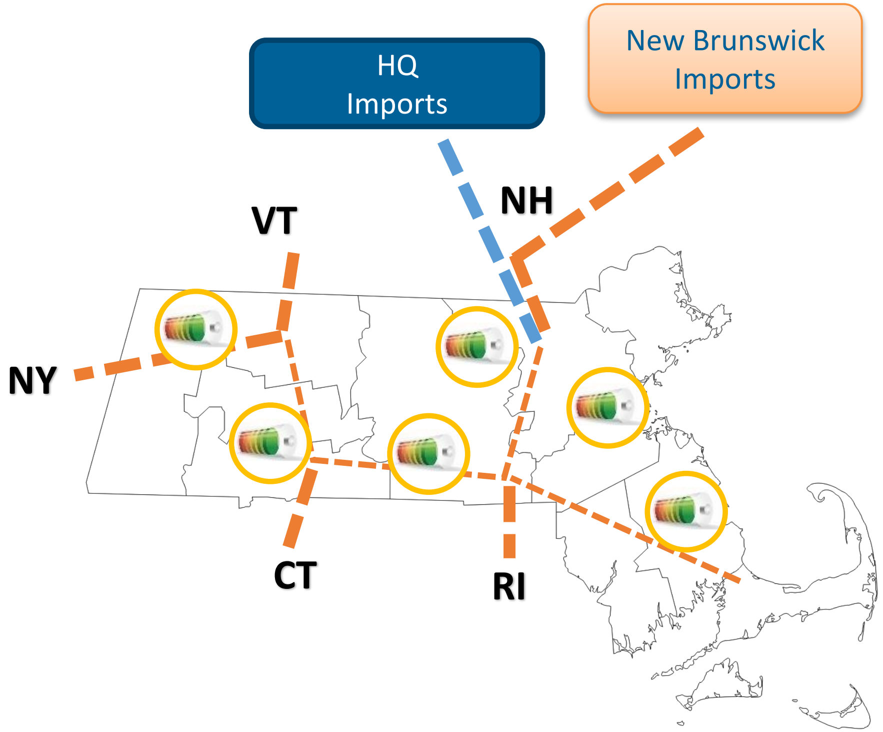


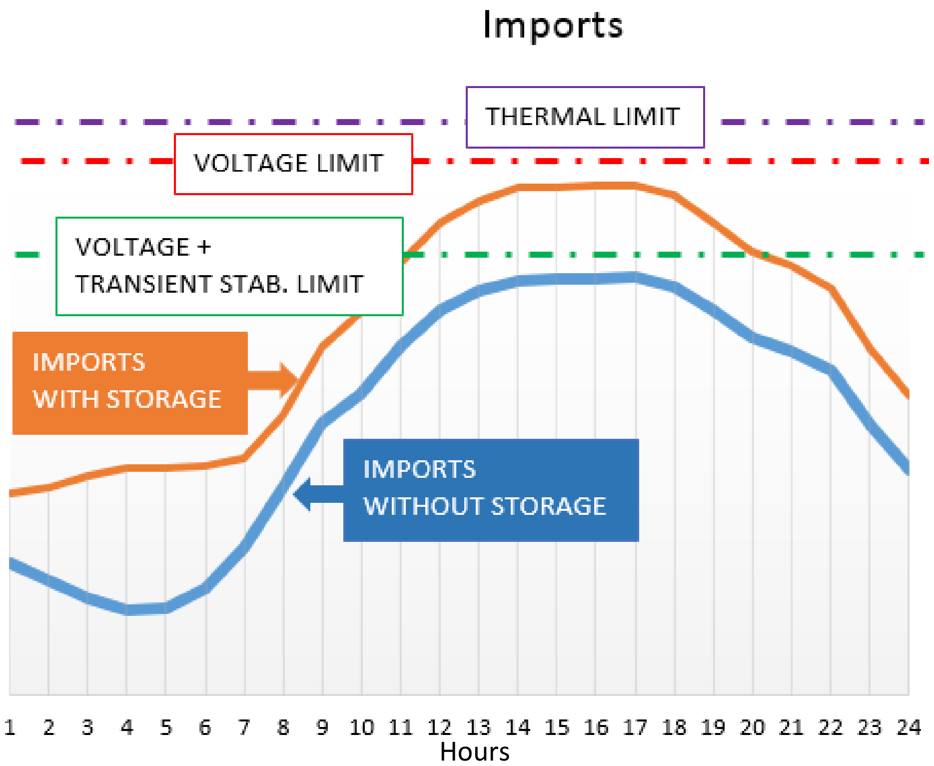


- Distributed energy storage deployment
  - Increase lifetime of T&D assets
  - Reduce maintenance requirement
  - Reduce high thermal risk due to full load utilization
  - Increase resiliency by reducing peak power
- System optimization could stabilize the voltage and reduce risks of transient stability issues

Part of the $305 million T&D cost reduction over 10 years.

Utilization of Imports



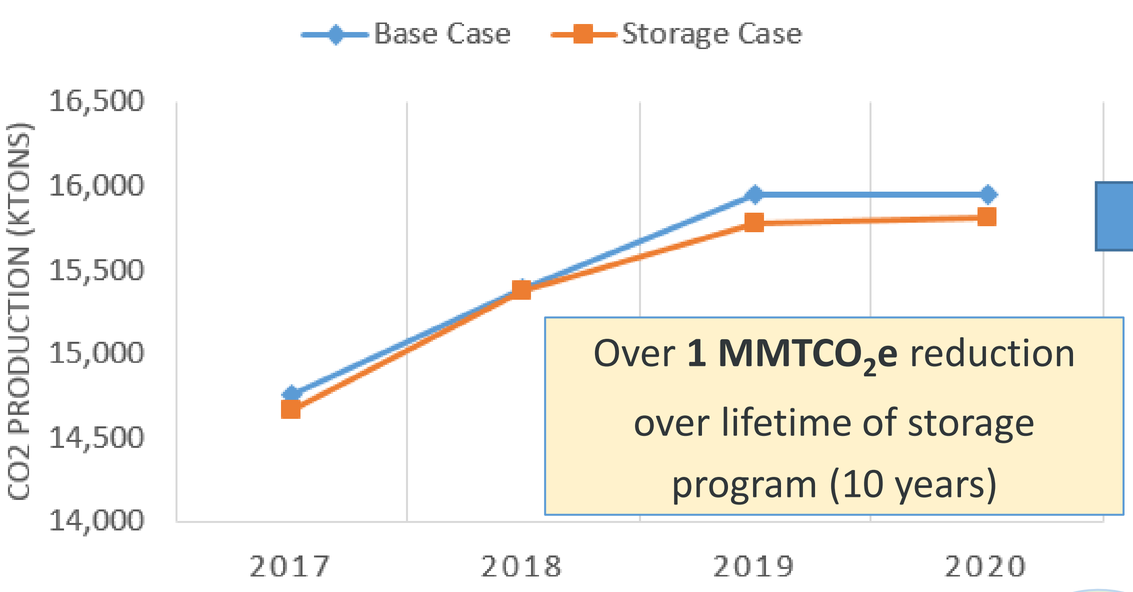


- Better utilization of existing and future imports after storage deployment in MA.
- Higher transfer capability of import lines due to utilization of line at voltage limit.
- Increased imports during off-peak hours when the price of electricity is low.

Storage will enable better utilization of existing import lines.

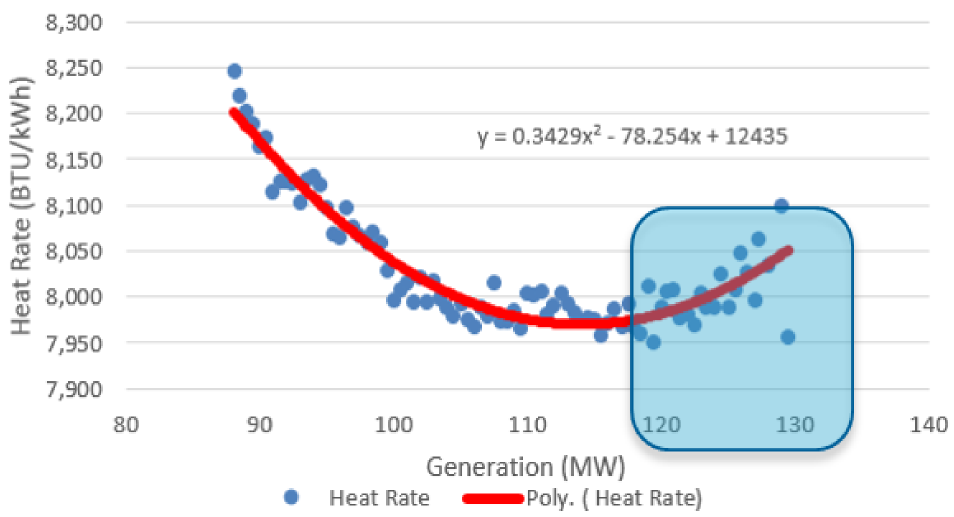
Emission Reduction

MASSACHUSETTS CO2 PRODUCTION

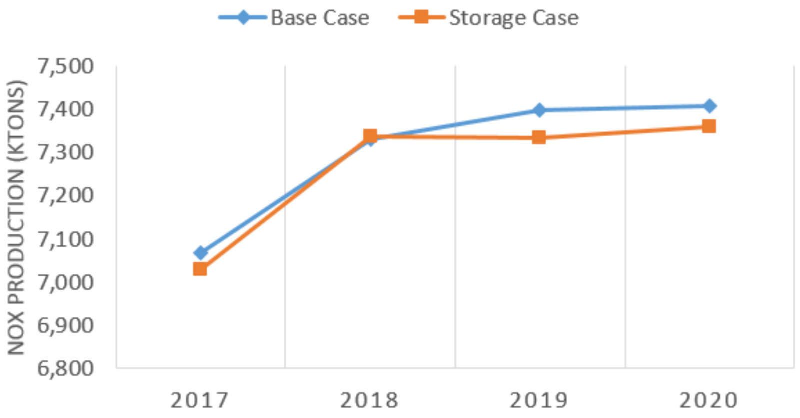


Over **1 MMTCO$_2$e** reduction over lifetime of storage program (10 years)

HEAT RATE OPTIMIZATION



MASSACHUSETTS NOX PRODUCTION



Part of the $197 million wholesale market cost reduction over 10 years.

- Storage is managing the systems fluctuations and intermittency and doing reserves
- The fossil fuel fleet can run more often at its optimum heat rate
- Greater efficiency means less fuel burned

Study Findings Summary

Opportunities:

Energy Storage has potential to provide benefits to the Massachusetts ratepayers, including:

- Reducing the price of electricity
- Lowering peak demand and deferring investment in new infrastructure
- Reducing the cost to integrate renewable generation
- Reducing greenhouse gas (GHG) emissions
- Increasing the grid's overall flexibility, reliability and resiliency
- Generating nearly $600 million in new jobs

Barriers:

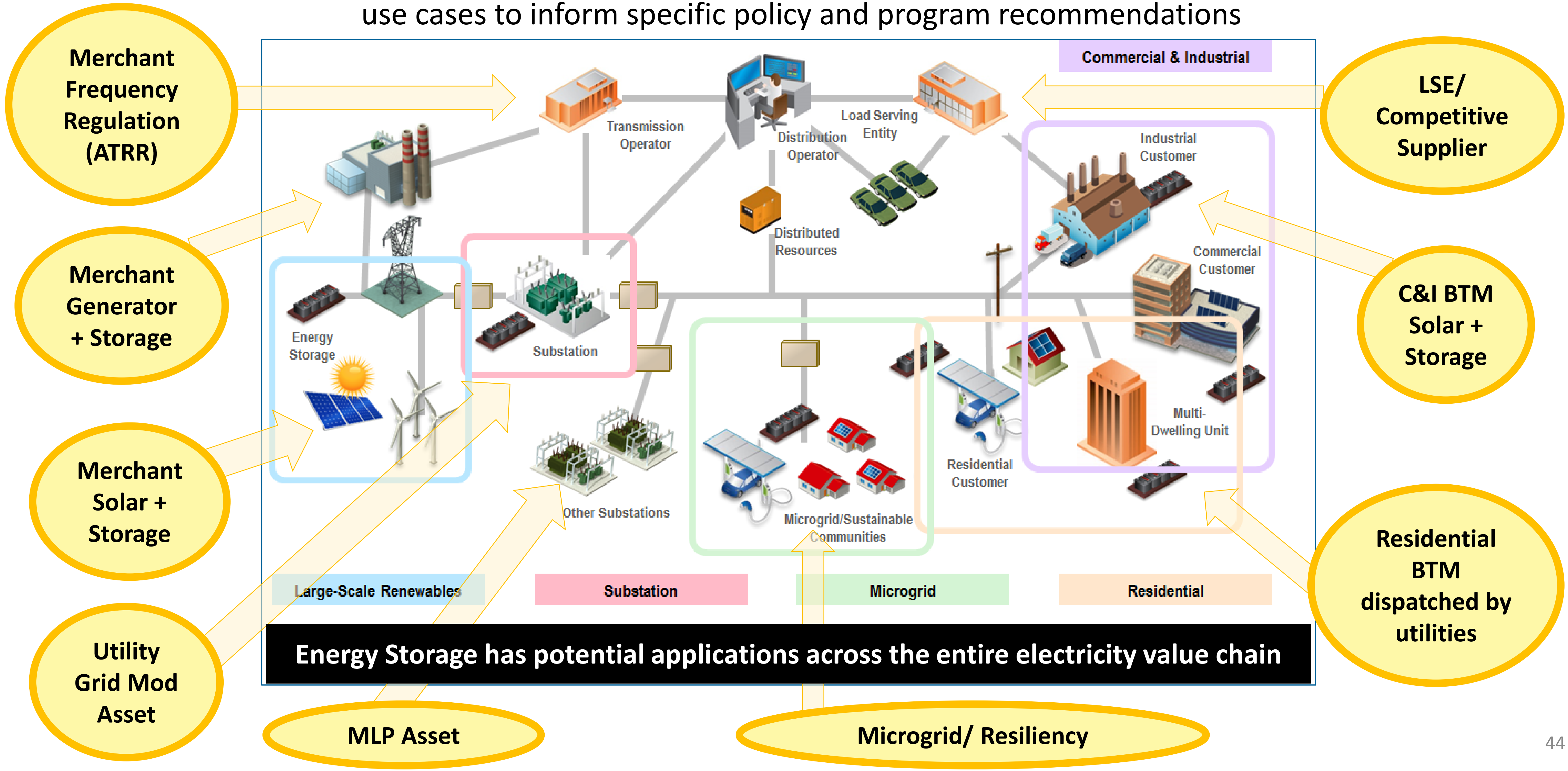
- Business models for storage in very early stages
- Energy storage systems need a way to be compensated for a greater portion of their value to ratepayers in order to achieve market viability

Energy Storage Application Use Cases

Analyses of specific applications and business models to utilize energy storage across the Massachusetts electric grid

Storage Use Cases

The Study analyzed the economics and business models of ten storage use cases to inform specific policy and program recommendations



System Modeled Results

Use Case		Estimated Share of 1766 MW Recommendation		Millions $		Benefit/Cost Ratio
		%	MW	Combined Benefits (Market Revenue + System Benefits	Cost	
Investor Owned Utility (IOU) Grid Mod Asset: Distributed Storage at Utility Substations		40%	707	1301	387	3.36
Municipal Light Plant (MLP) Asset		10%	177	446	97	4.60
Load Serving Entity (LSE)/Competitive Electricity Supplier Portfolio Optimization		8%	141	158	77	2.05
Behind the Meter	C&I Solar + Storage	6%	106	103	58	1.78
	Residential Storage	4%	71	19	53	0.49
	Residential Storage Dispatched by Utility	5.5%	96	129	39	2.43
Merchant	Alternative Technology Regulation Resource	1.5%	28	45	15	3.00
	Storage + Solar	10.5%	185	373	102	3.66
	Stand-alone Storage or Co-Located with Traditional Generation Plant	9.5%	168	405	92	4.40
Resiliency/Microgrid		5%	87	133	48	2.77

Use Case Evaluation

For each Use Case the Study Team evaluated the economics for making the investment in the storage by assessing:

1. The value the storage owner/developer can monetize through existing market mechanisms, and
2. The system benefits that would accrue to Massachusetts ratepayers should the investment in storage be made.

Use Cases		
Investor Owned Utility (IOU) Grid Mod Asset: Distributed Storage at Utility Substations		The storage systems would be owned and dispatched by the Investor Owned Utilities, i.e. Unitil, Eversource, and National Grid. The systems would be likely located at distribution substations with the locations selected by the IOUs to address local needs including high demand, reliability conditions, and renewables integration.
Municipal Light Plant (MLP) Asset		The storage systems would be owned and operated by a Massachusetts MLP and located within the municipality. Uses for the systems would be to lower the municipality's peak demand, capacity and transmission costs, as well as to provide local resiliency.
Load Serving Entity (LSE)/Competitive Electricity Supplier Portfolio Optimization		In Massachusetts LSE's provide the energy supply portion of a ratepayers IOU electricity bill. LSE's either offer competitive supply direct to consumers or provide IOU's basic service supply. An LSE would utilize storage as a means to hedge energy costs, purchasing low cost energy and providing stored energy during times of high energy cost, and to sell services in the ISO-NE markets.
Behind the Meter	C&I Solar Plus Storage	A commercial or industrial customer with on-site solar would own and operate a storage system to better utilize and firm the energy from the solar installation, allowing the C&I customer to reduce their reliance on grid energy during peak times, decreasing demand charges, and capturing the full value of their solar energy regardless of net-metering structure.
	Residential Storage	A behind the meter residential storage system can be owned by the customer and located within the home for resiliency during grid outages.
	Residential Storage Dispatched by Utility	Similar to the above Use Case, the storage system would be located in the home and provide resiliency but the utility would be able to dispatch the system to capture the grid benefits of peak demand reduction. The system could be owned by either the utility or the customer.
Merchant	Alternative Technology Regulation Resource	A merchant storage developer operates the storage system as an Alternative Technology Regulation Resource (ATRR) to provide frequency regulation in the ISO-NE market.
	Storage + Solar	A solar merchant project developer operates a storage system co-located with the solar resource to better integrate the solar generation into the energy market. The storage system allows the project developer to sell "dispatchable" and firm solar energy better aligned with peak demand, as well as ancillary services.
	Stand-alone Storage or Co-Located with Traditional Generation Plant	A gas or other fossil fuel generator would own and operate a storage system on site to allow the plant to run at optimal heat rate levels, utilizing the storage to provide fast ramping response and ancillary services.
Resiliency/Microgrid		A municipality or another localized energy user such as a university campus or medical center owns and operates the energy storage systems to provide peak demand reduction, reducing capacity or demand charges, while reducing the costs to provide backup power in the event of an outage.

IOU Use Cases:
Storage as a Utility Asset

- Storage distributed across a utility's system provides the utility a **large aggregated, flexible tool** to manage peaks, integrate renewables, and mitigate outages

- Storage has the potential to meet several of the objectives outlined in the DPU Grid Modernization proceeding:
  - Optimizing Demand by reducing system and customer costs at peak
  - Reducing the effects of outages
  - Integrating distributed resources, particularly Solar PV

Given the recent advances in energy storage technology and cost-effectiveness, it is hard to imagine a modern electric distribution system that does not include energy storage.

- IOU Grid Modernization Plan

Use Case #1: IOU Storage Asset

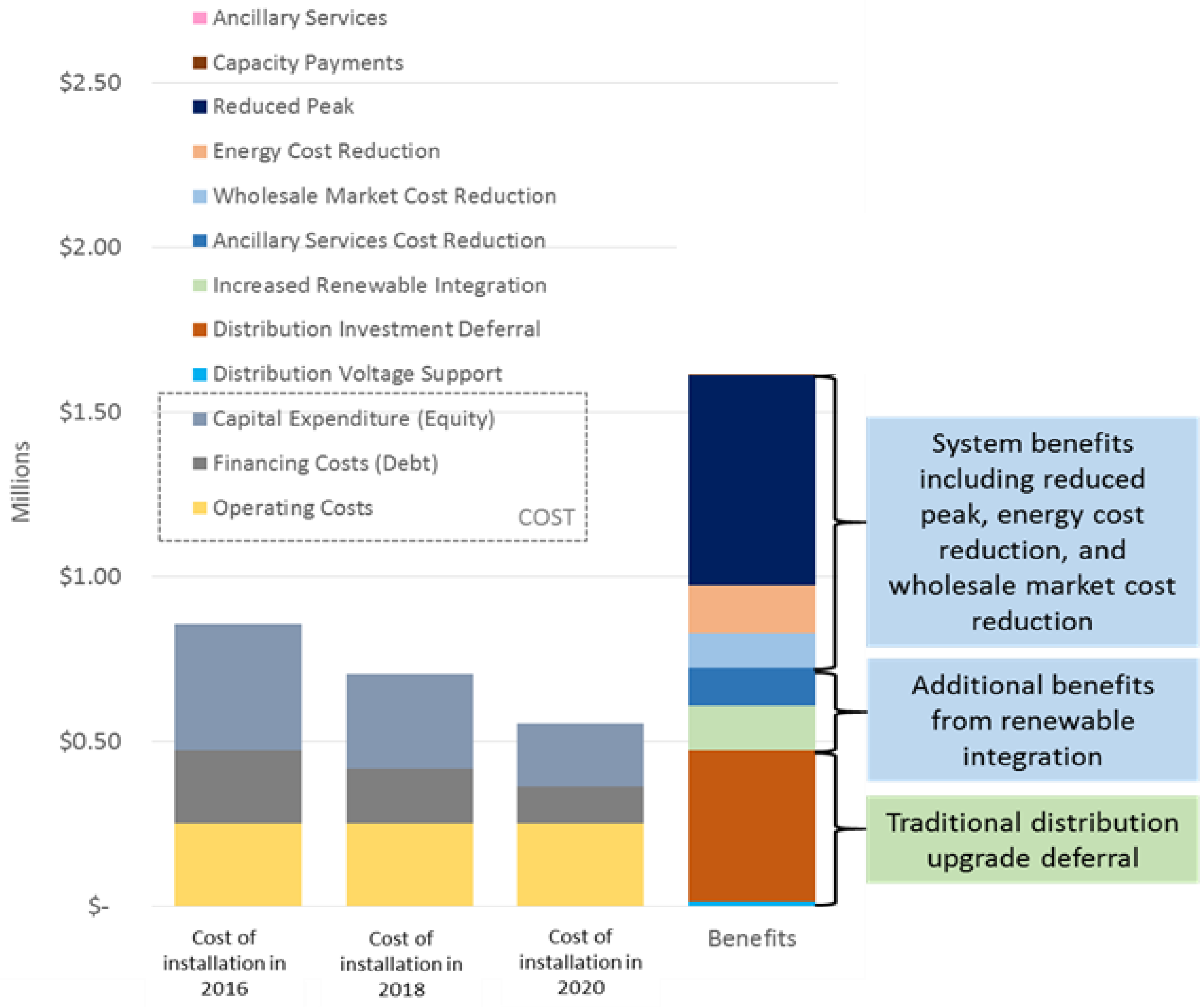
Utility Grid Modernization Plans may include storage if supported by a comprehensive *business case analysis*:

- Rationale and business drivers for the proposed investment
- Identification of all quantifiable and non-quantifiable benefits and costs

Benefit-Cost Analysis shows:

- Benefits must be monetized beyond traditional voltage support and upgrade deferral
- Cost effective when additional benefits are included
  - Renewable DG Integration
  - Peak Demand Reduction
- Additionally, sales to ISO-NE allowed in current legislation may offset storage costs to the ratepayer

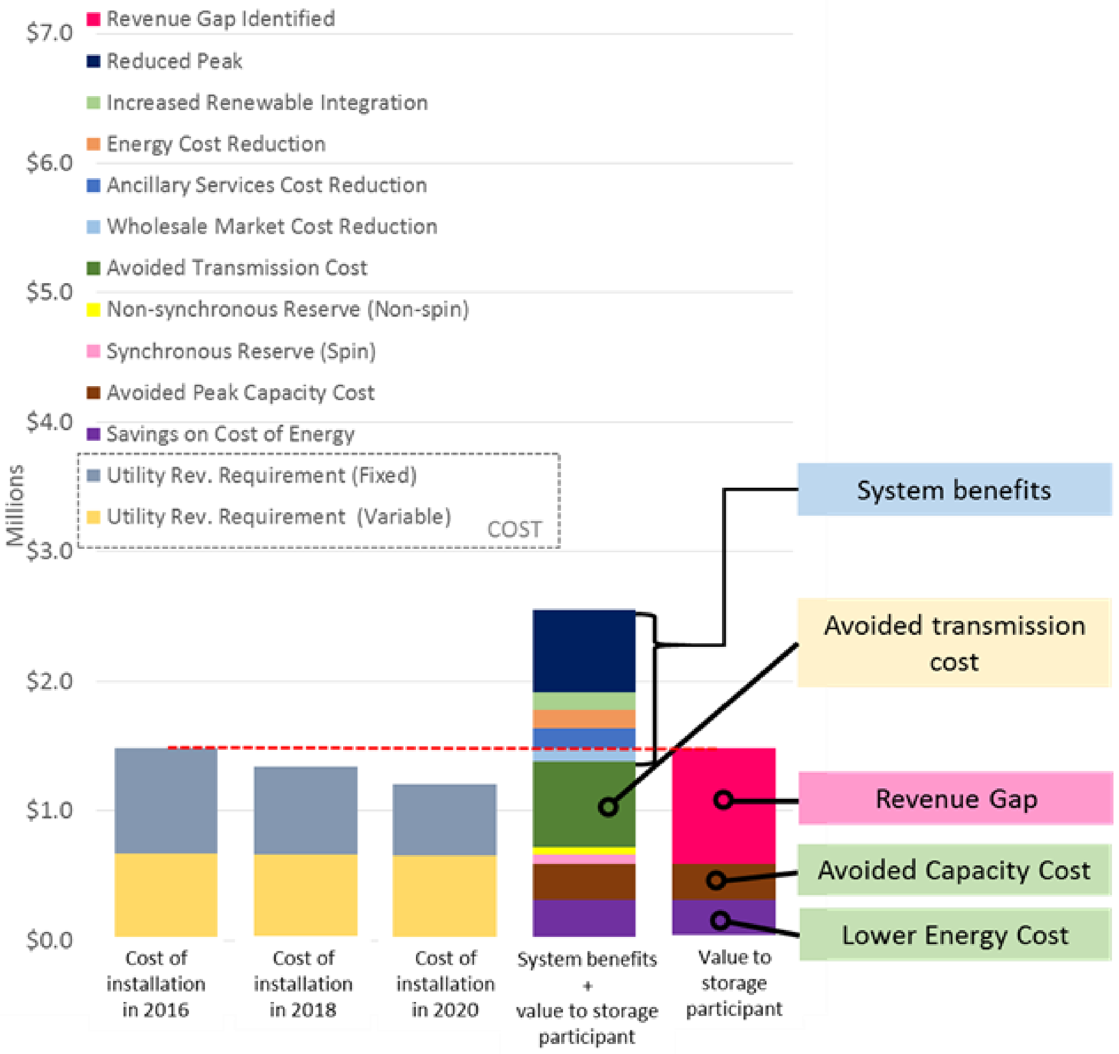
Benefit-Cost Analysis
1MW/1MWh



Use Case #2: Municipal Light Plant (MLP) Storage Asset

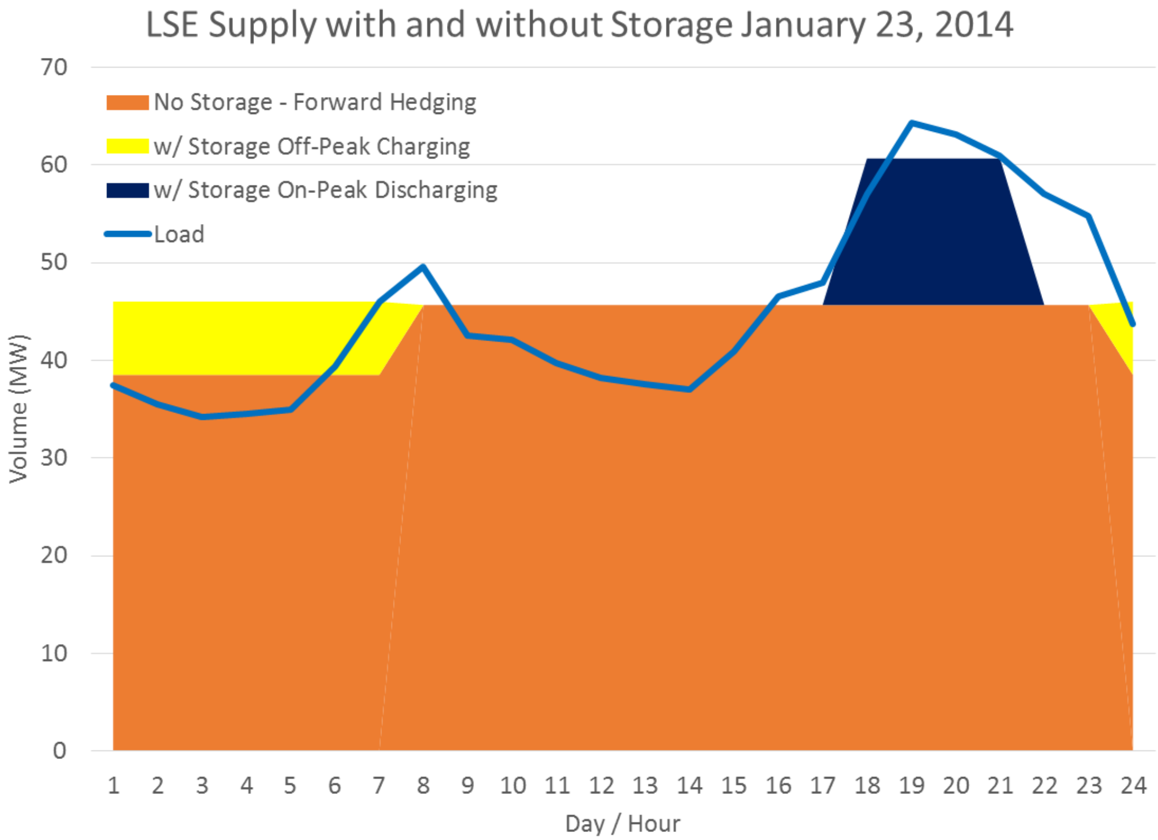
- Storage used to reduce MLP peak load, reducing its payments to the ISO and lowering cost of energy to serve its load:
  - Avoided peak capacity cost
  - Avoided transmission cost
  - Time shifting of energy to reduce cost
- However, MLPs cannot avoid the transmission cost under existing ISO-NE rules which hurts project economics
  - Under existing rules, if MLPs utilize generation or demand response to reduce the monthly peak, the ISO reconstitutes such generation and adds back to the transmission charges
- If storage is added to APS could monetize system benefits, while addressing load reconstitution rules

Benefit-Cost Analysis
1MW/1MWh



Use Case #3: Load Serving Entity

- **Load Serving Entities (LSE), or competitive suppliers, buy energy in the wholesale market and compete for business to serve retail loads**
  - **Either Direct sales to Businesses and Residents or Supply Basic Service to IOU**
- **Storage reduces the costs to serve loads**
  - **Hedge against volatility on the spot market. Shift energy from off-peak hours to peak hours to hedge against energy price spikes in the spot market. While price spike happens rarely, it can be a significant cost to the LSE**
- **Storage deployed in this way can effectively reduce the peak capacity requirement bringing in large system benefit**



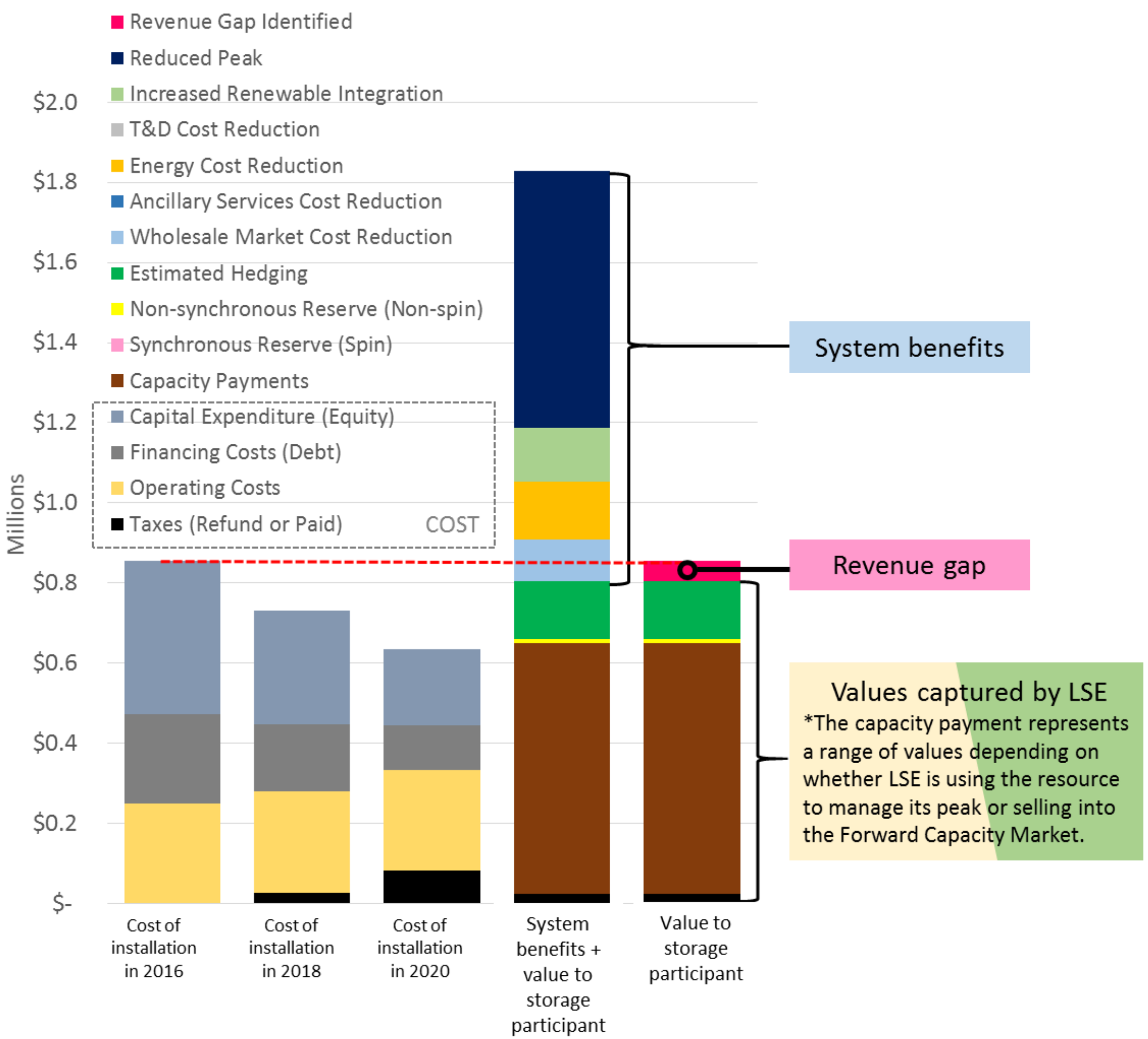
➢ **Example**: Winter peak day 1/23/2014

- LSE purchase from the spot market at $500 - $850/MWh at peak hours to make up for the difference between actual load (blue line) and hedged position (orange area)
- If the LSE has control over energy storage assets, it can charge the storage at off-peak hours (yellow area) with energy procured through the forward market and serve the load during the peak hours (dark blue area) with the stored energy
- The LSE can reduce its cost of serving the load from $171k to $132k, or a **23% reduction** for this day

Use Case #3: Load Serving Entity Storage Asset

- ➢ An LSE-controlled storage gives the LSE flexibility in serving its load
- ➢ Revenue streams captured by the LSE:
  - Hedging
  - Avoided capacity payments
  - Providing ancillary services in the wholesale market
  - ➢ Revenue justifies the cost of storage in 2020
- ➢ System Benefits Includes:
  - ➢ Reduced Peak
  - ➢ Increased Renewable Integration
  - ➢ Energy Cost Reduction
  - ➢ Wholesale Market Cost Reduction
- ➢ *When system benefits are included, the storage is cost-effective for ratepayers*
- ➢ To monetize system benefits storage could be added to the APS
  - Bridge the gap between cost of installation in 2016 and revenue to LSE storage could be included in the APS

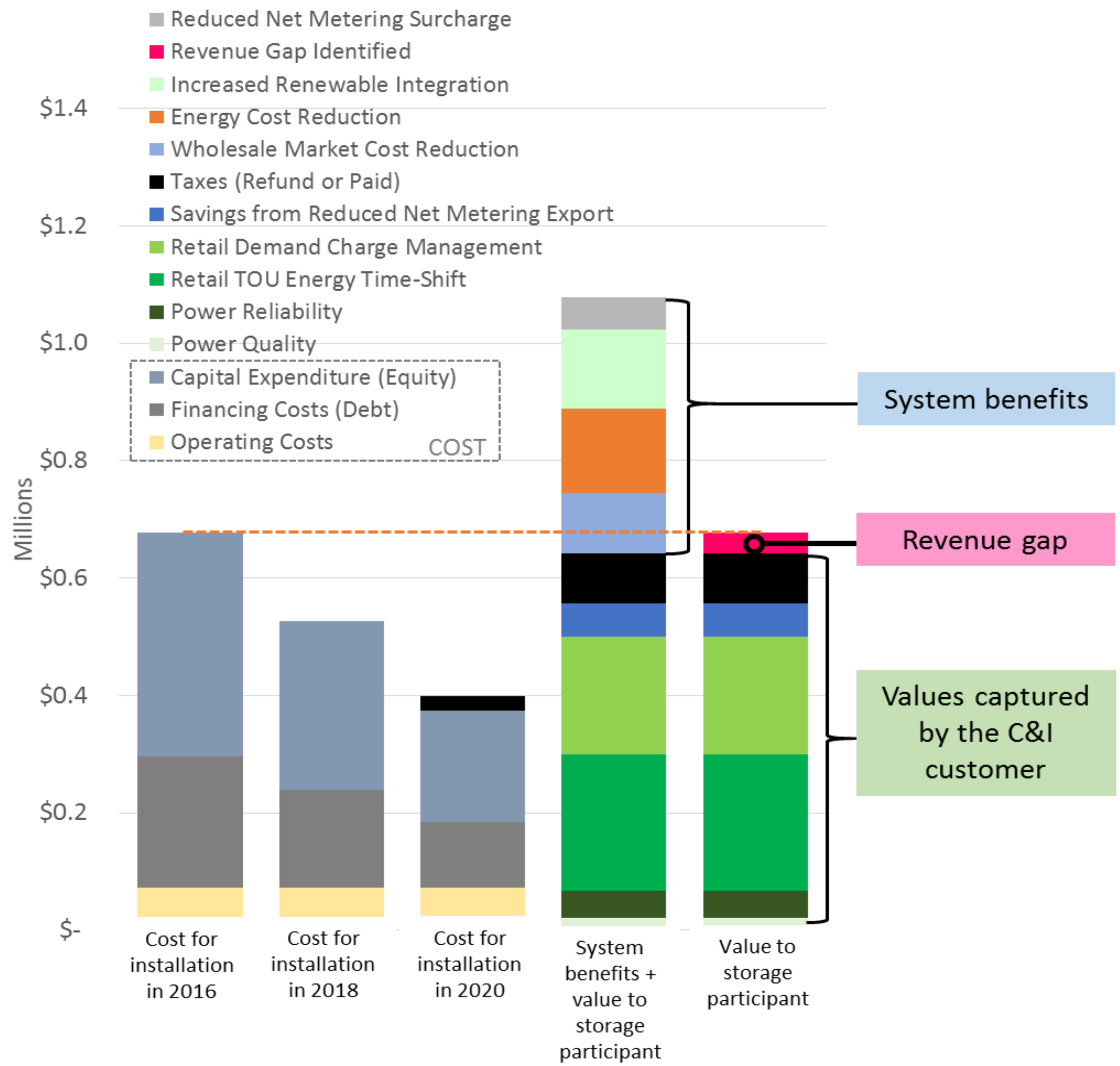
Benefit-Cost Analysis
1MW/1MWh



Use Case #4A: Behind the Meter C&I Solar + Storage Asset

- Business case for C&I customer
  - Savings from reduced net metering export
    - Instead of selling extra energy back to the grid, the C&I customer can store the energy locally, avoiding costs at the full retail rate as opposed being credited for exported power at the lower net metering credit rate
  - Reduced demand charge
  - TOU energy time-shift
  - Improvements on power quality
- When system benefits are taken into consideration, the benefits outweigh the cost
- Storage in APS can be used to monetize system benefits of storage and bridge the gap between cost of installation and savings

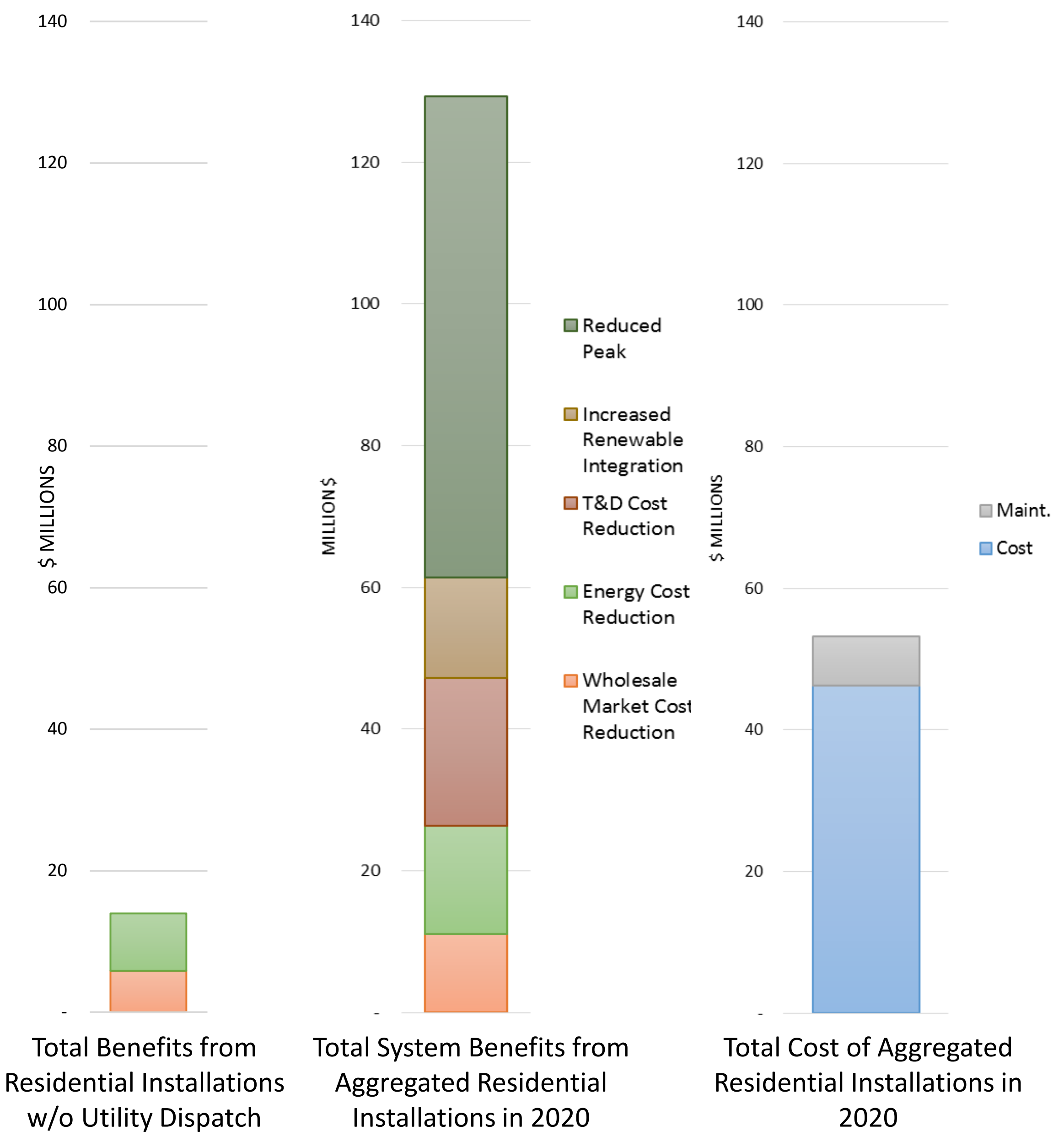
Benefit-Cost Analysis
1MW/1MWh



Use Case #4B: Residential

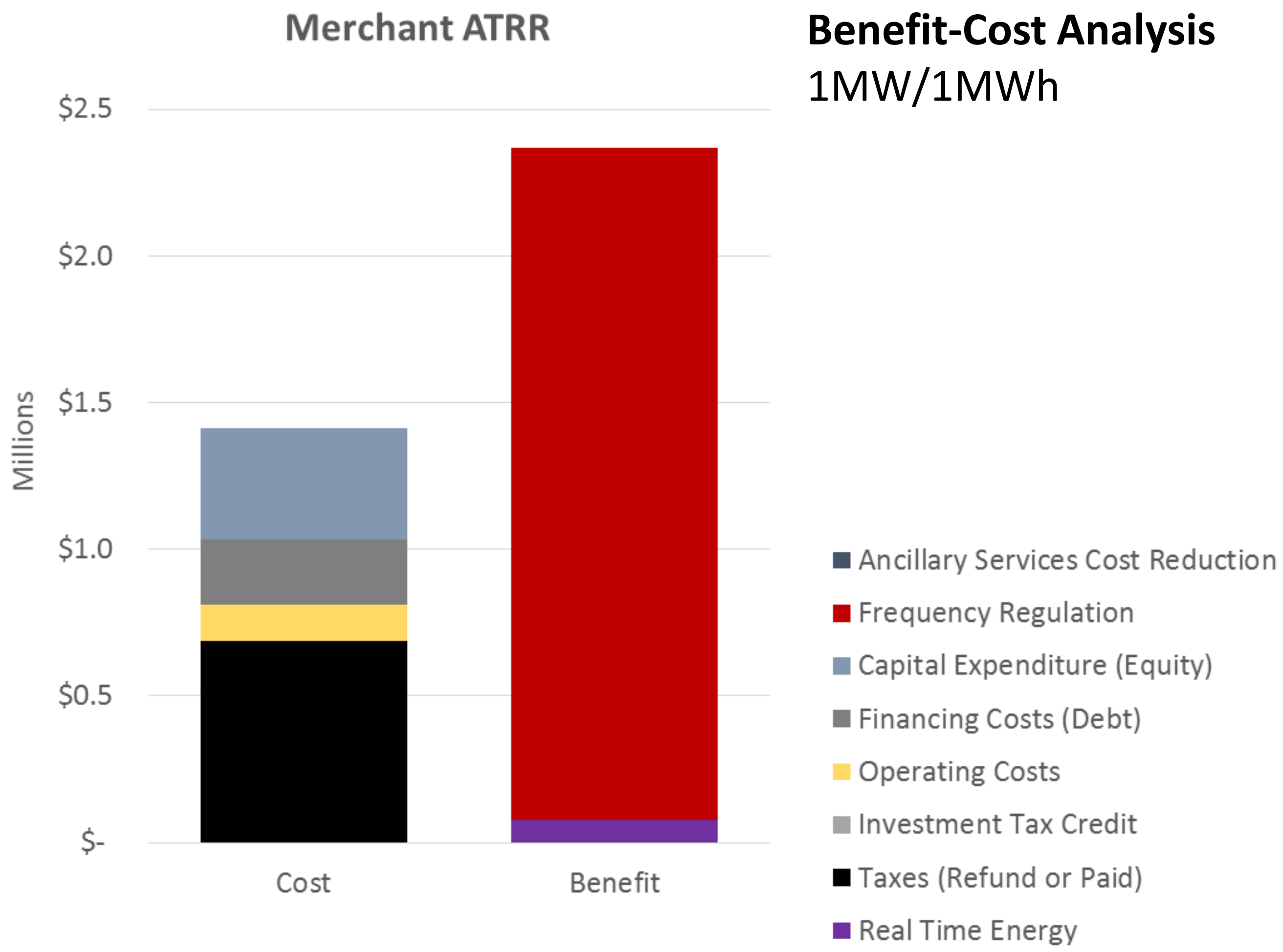
- The case for residential customers to install behind-the-meter storage (not necessarily with roof-top solar) was examined
- Without TOU rates and/or demand charges no signal to residential consumer to utilize storage in ways to maximize system benefits by time-shifting energy and reducing peak
- Power resiliency in emergencies is a primary benefit in such case, but it is difficult to quantify the benefit
- However, if the local utilities can dispatch these storage assets behind the meter, additional benefits can be unlocked and the case becomes cost-effective.
  - Reduced peak capacity cost
  - Reduced T&D cost
  - Increased renewable integration
- Examples: VT GMP/Tesla, MA Holyoke G&E, DOER/IOU/UMass DOE grant proposal for BTM solar + storage

System Benefits to Cost Ratio: 2.43



Use Case #5A: Merchant Alternative Technology Regulation Resource

- FERC Order 755 (October 2011) recognized that storage resources are significantly more effective at correcting system imbalances due to their near instantaneous response time
  - ISO-NE created Alternative Technology Regulation Resource (ATRR) for fast response storage to provide frequency regulation
- The cost of a storage project selling frequency regulation services into the ISO-NE market can be readily justified by the revenue it generates
- Most of the system benefits from this use case is already considered in the market mechanism by payments based on speed and accuracy of response (i.e. pay-for-performance)
- This is the only use case where storage is being fully compensated in the market for its system benefits



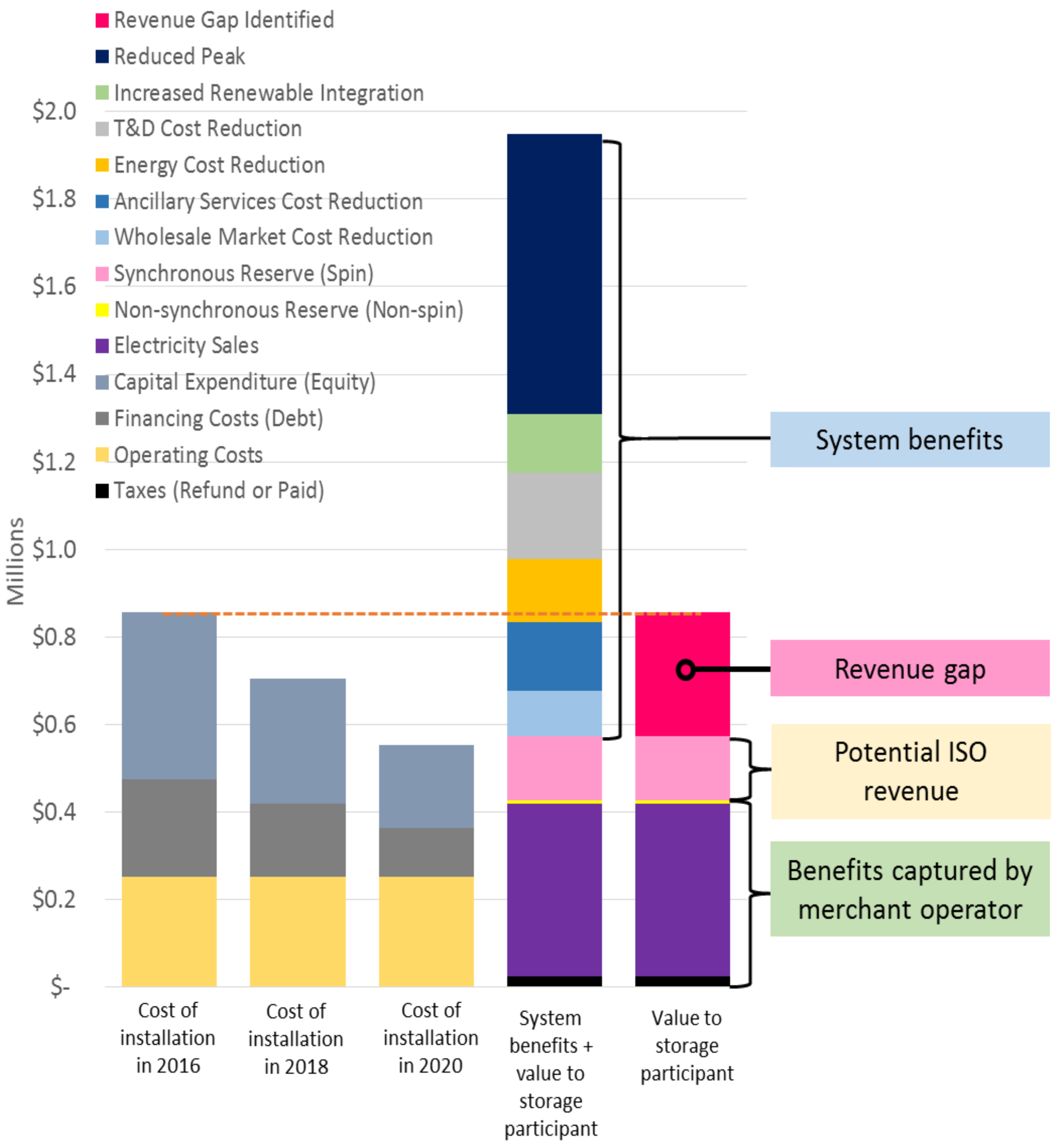
Benefit-Cost Analysis
1MW/1MWh

ISO-NE frequency regulation market is a viable wholesale merchant application for storage.
However, total Frequency Regulation market is small (currently only 70 MW). Expected to grow with renewables.

Use Case 5B: Merchant Solar + Storage Asset

- Storage can be co-located with solar to assist with solar integration.
- Reduces wholesale energy prices by replacing by fossil fuel generation when the sun is not available with that from solar power.
- Mitigates solar intermittency local power quality issues.
- Storage co-located with solar spreads out the generation of electricity, enabling better use of T&D lines
- Encouraging this business model could reduce reliance on net metering and reduce overall costs of net metering to ratepayers, while also providing greater system-wide benefits.

- Co-locating solar with storage could allow system owner to increase $/kWh value of wholesale energy by selling stored energy at peak rather than exporting in real-time.
- Current ability to virtually net meter provides little to no incentive for solar owners to sell energy at wholesale or make investments in storage, hampering development of such projects.
- With system benefits added in, the cost of storage is immediately justified. Extra incentive could be justified given the tremendous system-wide benefits that accrue from implementation of this business model.
- Incentive program could be structured to encourage co-location of storage resources and next solar incentive program could monetize storage co-located with solar



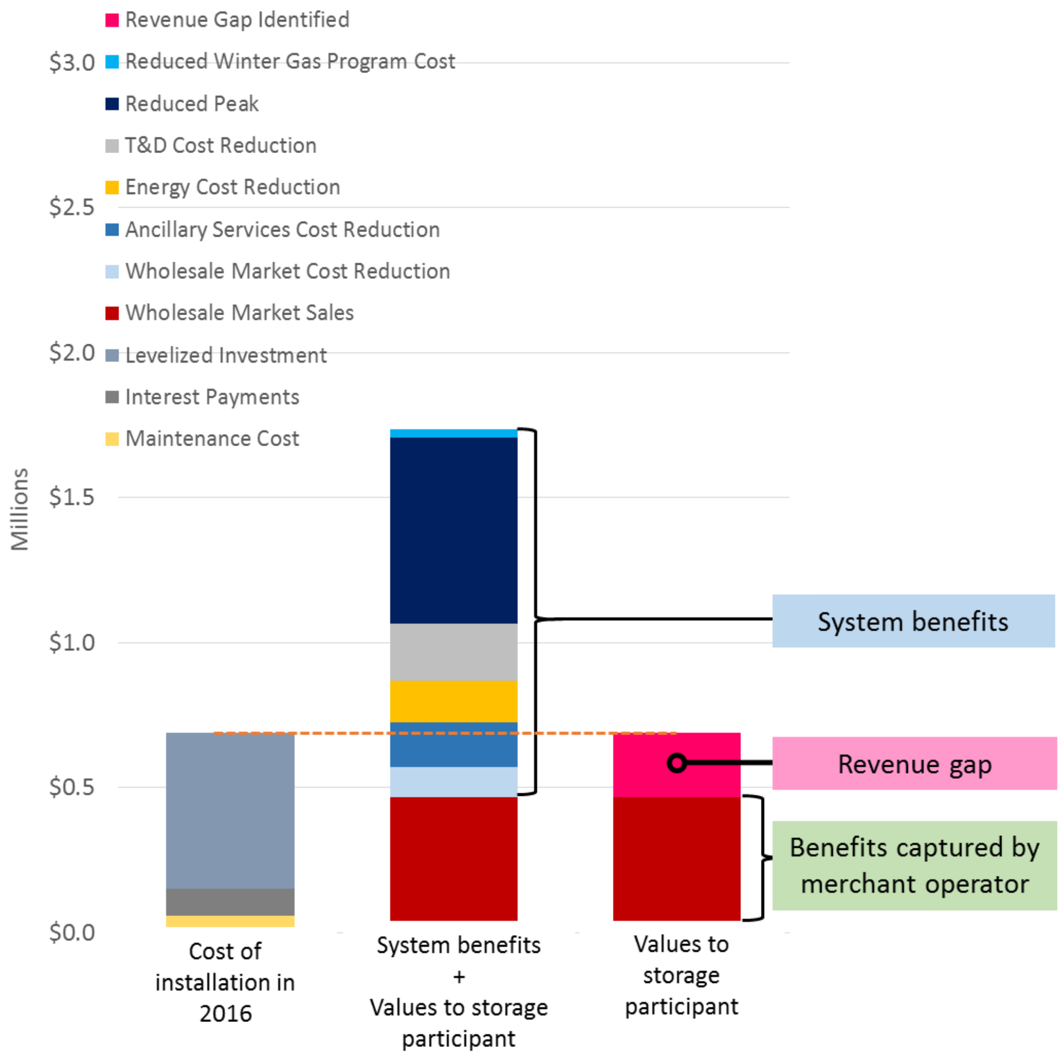
Use Case #5C: Merchant Gas + Storage Asset

- Storage, co-located or coordinated with a gas generator, is dispatched to work with wholesale markets to improve the efficiency of generators.
  - Storage can take over load ramping and frequency response responsibilities, allowing the generator to operate at constant output near optimal heat rate, reducing the associated maintenance costs and GHG emissions.
  - Storage enabling generators to operate at optimal heat rate is especially important to the North East in coping with gas shortage during the winter.
  - Storage described above can still participate in the wholesale market of ISO-NE.
- The electricity system benefits from more efficient operation of the generators, lower cost of ancillary services, lower energy price, easier renewable integration, reduced peak capacity cost, and lower emission.

- The storage asset would be dispatched to work with wholesale markets to improve efficiency of generators,
  - Reduce starts and stops
  - Reduce emissions
- The project is cost-effective if system benefits are included.
- Challenge: ISO-NE rules around co-located resources to be registered as a single asset and share responsibilities are unclear or do not currently exist.

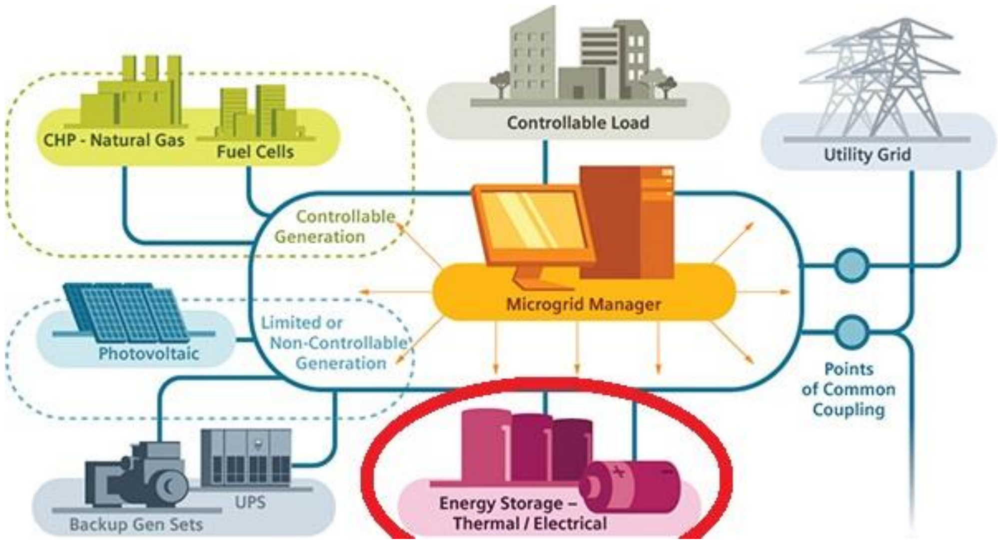
Benefit-Cost Analysis

1MW/1MWh



Use Case #6: Microgrid

Microgrid: Grid Connected Mode

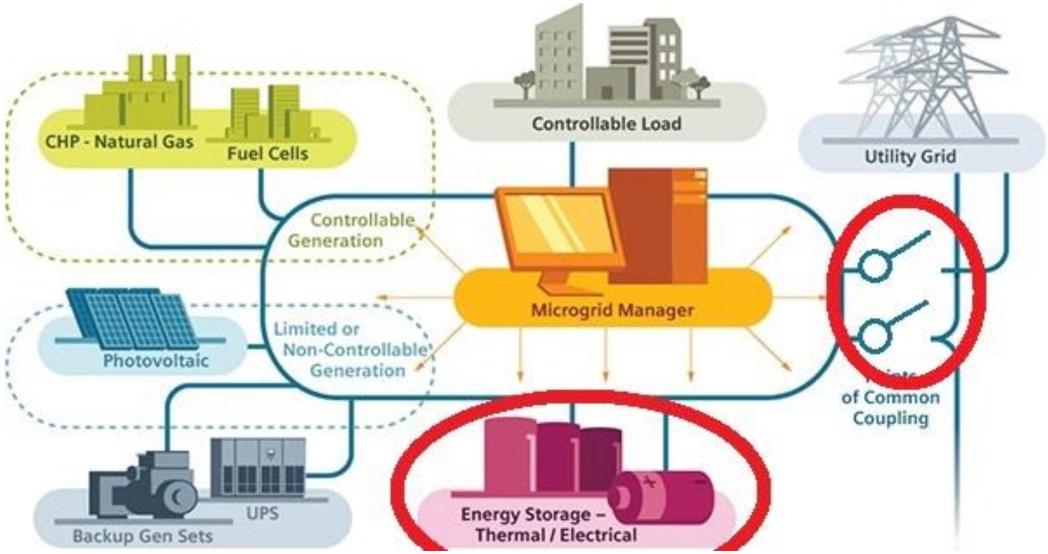


Benefits (similar to IOU/MLP use cases)

- Energy cost reduction
- Demand charge reduction
- Renewables Integration
- Transmission and distribution system cost reduction
- Ancillary services revenue
- Peak shaving/load following

One third of operating microgrids in US (1,300MW in 2015) include storage

Microgrid: Islanded Mode



Benefits

- Energy resilience/extend liquid fuel reserves
- Power quality
- Renewables Integration
- Peak shaving/load following

Average Cost Per Unserved kWh						
	Duration of Outage					
	Momentary	30	1 hr	4 hr	8 hr	16hr
Medium and Large C&I	$191	$37	$22	$12	$13	$13
Small C&I	$2,255	$474	$295	$214	$267	$258
Residential	$31	$6	$3	$2	$1	$1

The above values are reference from the "Updated Value of Service Reliability Estimated for Electric Utility Customers in the United States" Report from Lawrence Berkeley National Lab published online 1/2015.

Energy Storage Initiatives in Other States

Grants & Loans
Rebates & Incentives
Pilot Programs
Procurement Mandates & Targets

58

California: Energy Storage is an Important Part of the Resource Mix

- The Self Generation Incentive Program (SGIP)
  - Ratepayer-funded rebate program, overseen by the CPUC) $83 M budget in 2015
  - Incentives for storage up to $1,620/kW
- California Mandate - 1,325 MW of energy storage by the year 2020
- Aliso Canyon
  - Energy storage is being procured as a solution to alleviate electric reliability problems resulting from natural gas shortages
- Long Term Procurement Process (LTPP)
  - More than 250 MWs of energy storage have been procured via the LTPP
- Electric Power Investment Charge (EPIC) Program
  - $162 M per year, ratepayer funded
  - Applied R&D, technology demonstration & deployment, market facilitation

Energy Storage in New York

- NY Green Bank
  - A financial entity that leverages public and private capital to finance clean energy, including energy storage
  - By 2016, NYSERDA was managing full allotment of $1 B of authorized capital
- New York Reforming the Energy Vision Initiative (NY REV)
  - Utility Distribution System Implementation Plans (DSIPs) due November 2016
- The NY Prize (part of NY REV)
  - $40 million initiative providing support for new clean energy microgrids that will promote energy resiliency during grid outages
- NYSERDA RD&D
  - NYSERDA’s Energy Storage Chapter of the Clean Energy Fund Investment Plan describes investing about $24 M in energy storage R&D in next three years
  - Targeting costs such as permitting, customer identification, and safety validation
  - Close cooperation with NY-BEST, the voice of the energy storage industry in NY
- NYISO Initiatives
  - Energy Storage Integration will lower barriers for grid-connected storage
  - DER Roadmap will create asset category for dispatchable distributed resources

State Initiatives for Energy Storage are Growing Around the Country

Washington

- Department of Commerce: Clean Energy Fund Smart Grid Grants
    - $14 M in smart grid matching grants, $21 M in non-state funding
    - 3 utility-led demo projects using storage

Oregon

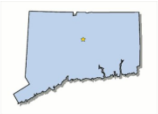
- Oregon Dept. of Energy Request for Grant Applications (RFGA) for utility-scale storage
    - Partner with DOE and Sandia National Labs
    - Eugene W&EB demo project of energy storage in a microgrid
- House Bill 2193-B (June 2015)
    - Utilities to propose rate-based storage procurements by 2018
    - Requires 5MWh procurement target by 2020 up to 1% of LSE's peak load

Arizona

- All Source RFP Solicitation Storage Requirement: 10 MWh of storage by end of 2018, via competitive RFP process

New Jersey

- Renewable Electric Storage Incentive Solicitation
    - $ 9 M commitment over 2015-16
- Solar Rebate Program expanded to also fund energy storage projects.



Connecticut

- CT-DEEP Clean Energy RFP: includes call for storage stand-alone or paired with renewables
- CT-DEEP Demonstration Projects for Distributed Energy Resources, includes storage
- Microgrid Grant - $30 million in current round

Maine

- Boothbay Smart Grid Reliability Pilot Project
    - Non-Transmission Alternative (NTA)
    - Includes PV, batteries, thermal (ice) storage
- PUC: Inquiry to establish a NTA coordinator

Policy and Program Recommendations

1. grow storage deployment in MA
2. Grow Storage Companies

Policy and Program Recommendations to grow the Deployment of Advanced Energy Storage in Massachusetts

Unlocking the Game Changing Potential of Storage in MA

Policy & Program Recommendations to Enable Cost-Effective Use Cases

Use Cases		Policies & Programs									Notes
		Grant and Rebates				State Portfolio Standard		Regulatory Treatment			
		ESI RFP	MOR-Storage Rebates	Resiliency Grants	Green Communities	APS	Solar Incentive	Grid Mod	EE Plan: Peak Demand	ISO-NE Market Rules	
IOU Distributed Storage at Substations		•				•	•	•	•	•	Tremendous system benefits and can be incentivized through existing Grid Mod Order, EE Plans, rate filings
MLP Utility Asset		•				•	•			•	APS can close revenue gap while addressing load reconstitution and ISO market barriers
LSE/Competitive Supplier portfolio optimization		•				•	•			•	Storage in the Portfolio standard will monetize the system benefits and close revenue gap
Behind the Meter	C&I solar + storage	•	•		•	•	•		•	•	APS and/or solar incentives that include a storage component will grow use storage with solar. Utility EE Plan Peak Demand Savings programs may have role.
Behind the Meter	Residential storage dispatched by utility	•				•	•		•	•	Utility or third-party dispatch of residential storage can reduce peak and increase renewable integration potential
ISO/ Merchant Developer	Alternative Technology Regulation Resource	•				•				•	ISO rules enable storage for frequency regulation, but would benefit from reduced minimum size
ISO/ Merchant Developer	Storage + Solar	•				•	•			•	Provide alternatives to net metering for standalone solar projects
ISO/ Merchant Developer	Stand-alone Storage or co-located with NG plant	•				•				•	Opportunity to increase efficiency of NG plants, need ISO market rule development
Microgrid	Resiliency case	•		•	•	•	•			•	Resiliency grants for critical C&I (e.g. hospitals) Add to Green Communities grant programs to incent municipal resiliency

Recommendations to Unlock the Use of Storage in MA

Grant and Rebate Programs

- **Energy Storage Initiative (ESI) RFP**
  - Launch Project Demonstrations for Use Case Business Models to Jump Start market
- **Rebate Program for Customer-sited Storage ("MOR-Storage")**
  - Encourage BTM Storage where it can reduce cost of electricity and create system benefits through reduced peak demand and greater utilization of on-site generation
  - Funded through $20 million ACP
- **Launch C&I Solar + Storage Feasibility Grant programs**
  - Assist businesses and manufacturers to evaluate adding BTM storage
  - $150,000 Mass CEC program
- **Community Resiliency Grants – Part III**
  - Resiliency grants for critical C&I (e.g. hospitals) which may include storage, $14 million
- **Green Communities Designation and Grants**
  - Enable storage as a technology in grant applications

Recommendations to Unlock the Use of Storage in MA

Storage in State Portfolio Standards

- **Add All Types of Advanced Energy Storage to APS**
  - ➢ Conduct Rulemaking to amend APS to Include All Types of Advanced Energy Storage
  - ➢ Monetize the Ratepayer System Benefits of Storage
  - ➢ Helps close project revenue gap by creating supplemental revenue stream for benefits created
- **Evaluate Storage in development of Next Generation Solar Incentive Program**
  - ➢ Encourage Use of Storage where solar + storage can provide more value to both the system owner and ratepayer than a net-metered facility would otherwise provide

Recommendations to Unlock the Use of Storage in MA

ESTABLISH/CLARIFY REGULATORY TREATMENT OF UTILITY STORAGE

- **Storage as a Utility Asset**
  - ➢ Ability to include Storage in Grid Mod Plans exists under DPU Order 12-76-B
    - Current Utility Plans include storage demo projects
  - ➢ May be opportunities in other proceedings such as rate cases
  - ➢ May be worthwhile to open further investigation on storage specific issues

Comprehensive Clean Energy Diversification Legislation signed Aug 8 2016 (H. 4568) clarified ..

- Utilities May own storage
- Storage is defined

- **Storage as Peak Demand Savings tool in EE Plans**
  - ➢ Green Communities Act calls for all cost effective energy efficiency <u>and</u> demand management
  - ➢ In 2016-2018 Plans new focus on Peak Demand Savings – includes demonstrations and assessment of current incentives and cost-effectiveness framework; DOER funding for demonstrations
  - ➢ Storage has been identified as opportunity but current DPU guideline benefit-cost test methodology may need changes to accommodate demand reduction programs
  - ➢ Process will include examining a variety of business models, including competitive (non-utility owned) solutions aggregating BTM storage and deliver its benefits

Recommendations to Unlock the Use of Storage in MA

OPTIONS THAT INCLUDE STATUTORY CHANGE

- **Allow bids that have energy storage components in any possible future long-term clean energy procurements**
  (e.g., St. 2012, c. 209, § 36 “Section 83A”)
  - ➢ If this option is pursued, it is recommended that a clear definition of what constitutes a qualifying “Energy Storage System” be included within the statutory program.
    - Other states, including California and Connecticut have adopted statutory definitions for Energy Storage Systems, which may serve as useful frameworks for a Massachusetts definition.

Comprehensive Clean Energy Diversification Legislation sign on Aug 8 2016(H. 4568) clarified..

- Storage may be paired with clean energy bids

Recommendations to Unlock the Use of Storage in MA

ISO MARKET RULES

- **Challenges**
  - Storage Cannot Fully Participate in All Markets
  - ISO-NE cannot utilize energy storage as a flexible resource
  - Energy storage is not on level playing field
- **Recommendations**
  - Create an Advanced Storage Working Group at ISO-NE
  - Create Storage-Specific Rules
    - Optimization, Bidding, Scheduling and Dispatch for Energy and Ancillary Services
    - Capacity Market
    - Interconnection
    - Transmission Planning
    - Behind the Meter
    - Load Reconstitution

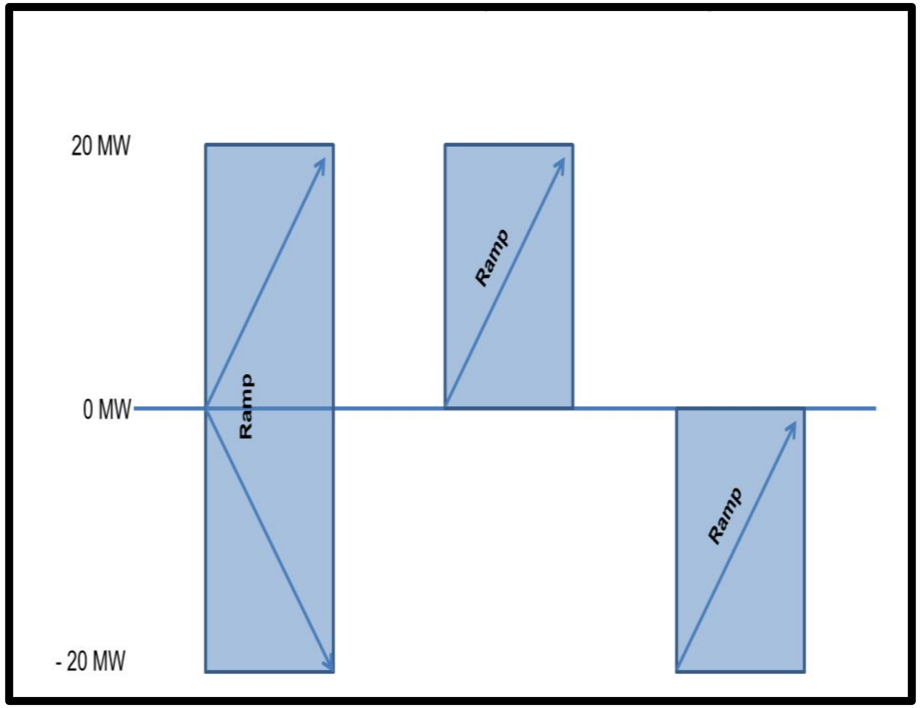
ISO-NE Does Not Yet Have Designated Rules for Advanced Energy Storage Beyond Frequency Regulation

- Current Rules allow Limited Participation by Energy Storage
  - Energy Storage Can be an ATRR and provide Frequency Regulation
  - Energy Storage Can participate as Pumped Hydro

- Advanced Energy Storage Capabilities are Different than Pumped Hydro
  - Can provide Full Range – From Negative to Positive, with zero transition time
  - State of Charge Must be Considered in ISO systems

- Need New Rules for: Optimization, Bidding, Dispatch and Settlements

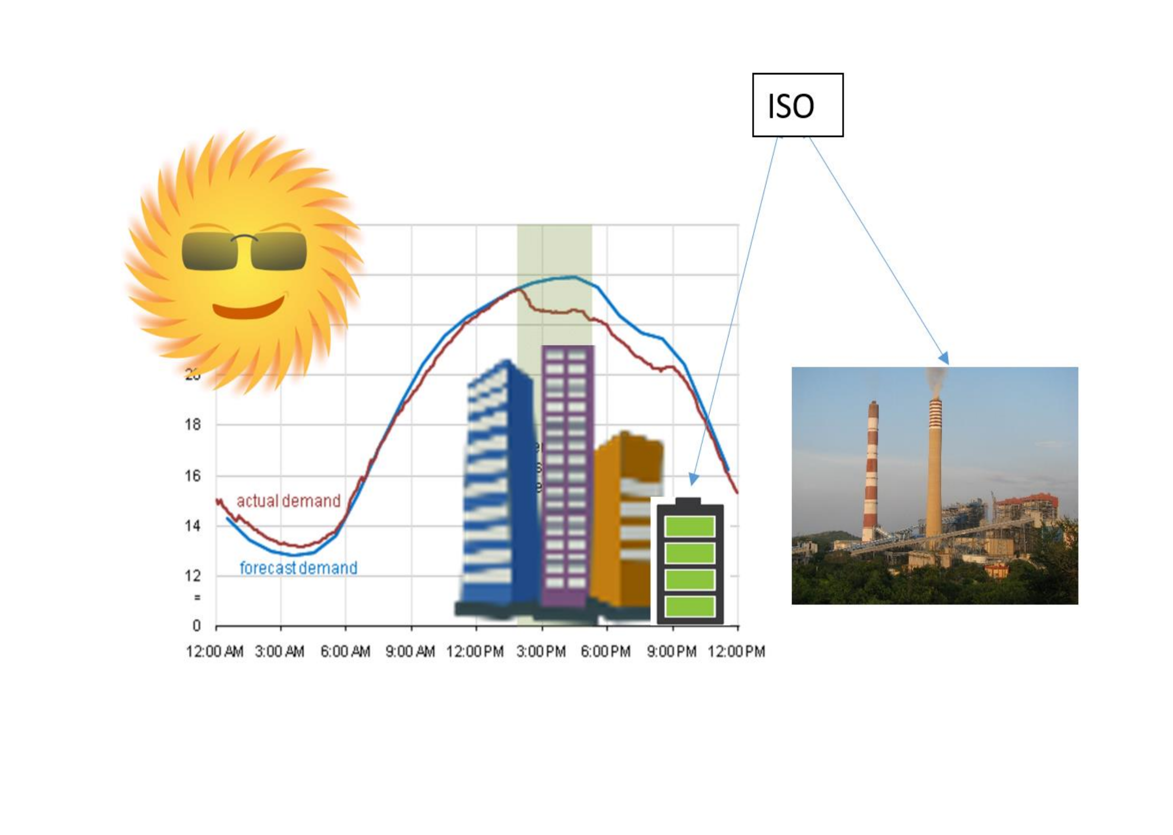
So that Advanced Energy Storage can fully participate in the Energy, Ancillary Services, and Capacity Markets



Like a generator, the full range Is dispatchable, and can provide capacity, energy, ancillary services, much more than frequency regulation, and not like pumped hydro.

Energy Storage From Behind the Meter Is Not Defined

- ISO-NE's rules do not yet consider Storage-specific requirements for Demand Response
- No consideration yet of:
  - Sub-metering
  - Baseline
  - Duration for Capacity
- Storage is not yet considered in the Transitional DR program for participation in the Energy and Ancillary Services markets

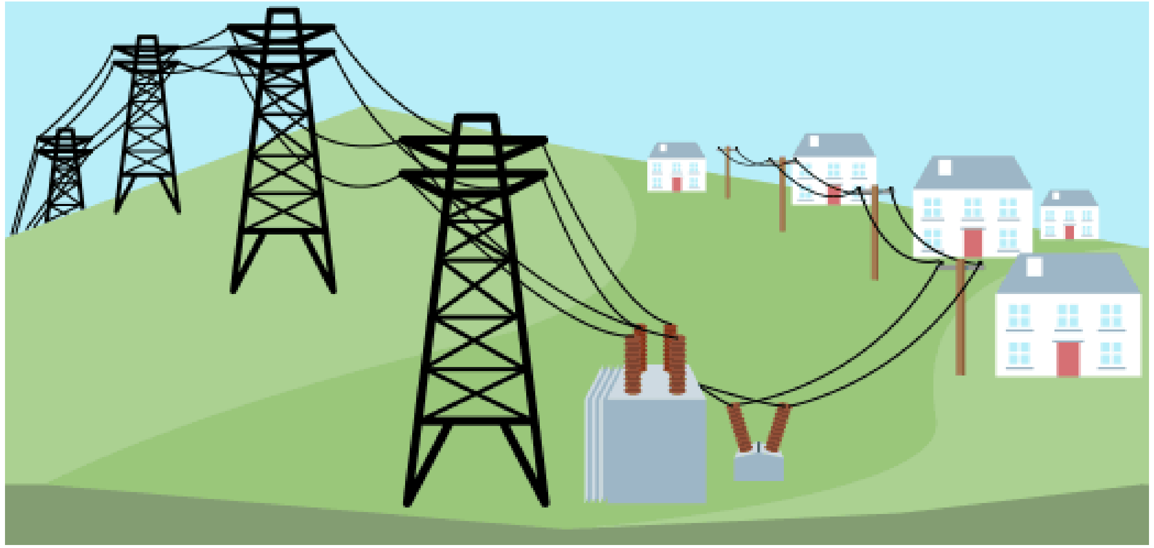


Energy storage as DR is dispatchable by the grid operator. It can provide capacity, energy, ancillary services, much more than frequency regulation.

Energy Storage Can Also Be a Transmission Solution

- Rules at ISO-NE do not yet consider energy storage as part of the Transmission Planning Process

- Other markets, such as California, consider how Advanced Energy Storage can be used to mitigate congestion and defer transmission investment in their planning process.
  - Reliability Studies incorporate Energy Storage
  - Information about locations where energy storage can mitigate a reliability need, and the duration requirements, are shared with stakeholders.



Energy Storage can be used to mitigate congestion and defer transmission investment.

Recommendations to Integrate Storage at ISO-NE

Encourage ISO-NE to Begin an Advanced Storage Working Group to Discuss the Following Recommendations:

- Develop market rules for Energy Storage Today – Don’t Force Fit
  - Energy, Capacity, and Ancillary Services
  - Optimization, Bidding, Dispatch, Scheduling, Settlements
- Minimum Size requirements – Change from 1 MW to 0.1 MWs
- Interconnection
  - Clear Rules for Study Process
- Transmission Planning
  - Identify in the Planning Process where Storage Can be A Reliability Solution
- Behind the Meter Participation (DR)
  - Sub Metering, Retail, Wholesale
- Load Reconstitution – Define BTM Load and Match Definitions with TOs

Recommendations to Unlock the Use of Storage in MA

OTHER CHANGES

- **Ease Interconnection**
  - Pre-approved standardized and certified systems would give applicants greater certainty of interconnection time and cost and the IOUs and ISO-NE a greater assurance the interconnecting systems will have de minimis impact on the grid
- **Safety and Performance Code and Standards**
  - Work with national organizations to provide input into the codes and standards development
  - Work with local authorities to adopt and implement the codes and standards
- **Customer Marketing and Education**
  - Increase customer marketing and education to protect customer investment and accelerate market adoption
  - Leverage existing programs (e.g., energy efficiency programs) to educate customers and market energy storage
- **Quality Assurance**
  - Support market adoption of energy storage with quality assurance mechanisms to protect customer investment
  - Programs can be adapted from similar experiences from solar

Policy and Program Recommendations to grow the Energy Storage Industry in Massachusetts

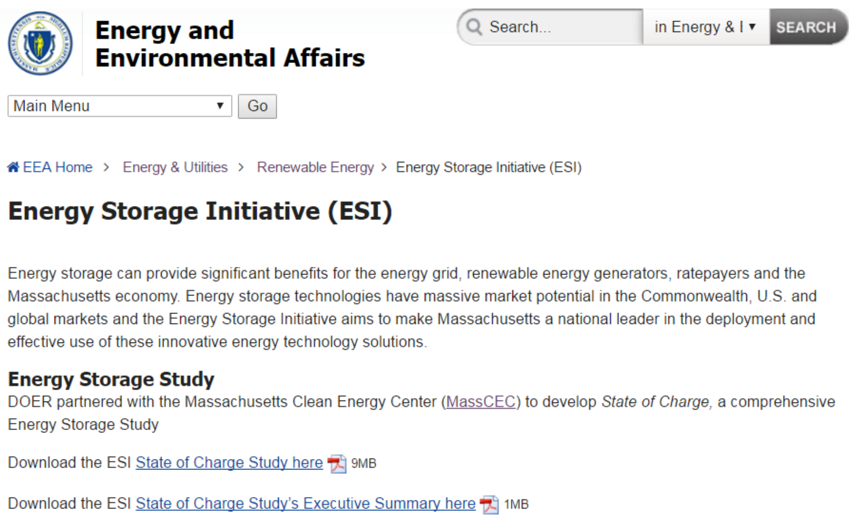
Recommendations to Unlock the Use of Storage in MA
GROW COMPANIES

- **Increase Investment in Storage Companies**
  - Create an energy storage cluster in Massachusetts to create jobs and maintain leadership in storage
  - Expand MassCEC Investment Programs to support energy storage companies in Massachusetts
- **Workforce Development**
  - A trained workforce is required to support the large scale deployment of energy and the growth of the energy storage industry
  - Expand existing MassCEC programs (e.g., Capacity Building, Internships) to support developing a trained workforce
  - Targeting existing capacity and market trends (e.g., training solar installers to install energy storage as well) will lead to efficiencies and market preparedness
- **Continue Support of New Technology Development**
  - Strong energy storage expertise in Massachusetts' world class universities supports creation of energy storage startups in Massachusetts
  - Invest in research and development, testing facilities to anchor an energy storage cluster in Massachusetts

NEXT STEPS AND TIMING

Next Steps and Timing

- State of Charge Study Release 9/16/16
- State of Charge Stakeholder Session 9/27/16
- Peak Demand Reduction Grant In-Process
- End of October Initiate Stakeholder Process and Panel Sessions Regarding Legislation Energy Storage Component
- Release RFP for ESI Demonstrations end of October
- Resiliency Grant program RFPs in October
- Include Storage in development of Next Generation Solar Incentive Program
- DOER Determination whether to set energy storage targets 12/31/16



Stay up to date by joining the ESI mailing list at: http://www.mass.gov/eea/energy-utilities-clean-tech/renewable-energy/energy-storage-initiative/